A MULTI-DIMENSIONAL STUDY OF INDICES OF ACTIVATION

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CONTENTS

PREFACE

This study is divided into five sections. First of all it presents a survey of the concept of generalised arousal or activation level; secondly, a broad survey of a selection of variables all of which have at one time or another been considered as indices of activation; thirdly, a survey of the quantitative methods which have been employed; fourthly, an account of a series of experiments in which the selected variables were examined in relation to certain performance criteria; and fifthly, a discussion of the results obtained.

It seems that any attempt to examine neurological and physiological function and behaviour tends to produce alternately, reasonably clear constructions which are almost immediately clouded by further research, and periods of confusion. I hope that this study at least will not add to the present confusion within the field of activation research, freely admitting that any errors, omissions and misapprehensions likely to do so are entirely my responsibility.

Over the four years or so that I have been engaged on this study a number of friends and colleagues have aided me considerably. Dr Raymond Corteen first aroused my interest in this field and was my supervisor during the preparation and planning of the experiments. Dr Boris Semeonoff has kept a friendly eye on the later stages of the project and has provided

support and comfort on a number of somewhat difficult occasions. Mr Tim Regan provided good humour and his considerable expertise when the apparatus was being set up and tested. Mr Bob Bell helped to contact subjects when he was Research Officer of the Sir Godfrey Thomson Unit for Educational Research. My wife, who subsequently occupied that post, carried on with the good work. She also typed the drafts and final copy of the thesis after grappling with irritations like getting suitable paper cut to a size which would conform to the Edinburgh regulations in a country where 'large quarto' or 'thesis size' seems to be unknown. How can one possibly give adequate thanks to a wife? Mr Roy Middleton of the Regional Computer Centre gave me a great deal of advice in the selection of suitable programs for the data analysis and thus speeded up the appearance of results after the tedium of data extraction. A number of discussions with Mr Jim Closs on the vagaries of factor analysis helped me greatly. The Headmasters of a number of Edinburgh schools allowed their boys to take part in the experiments and I thank them and their pupils as well as the volunteers from the University student body. The help, encouragement and friendship I have received from these individuals and many others, particularly the members of staff of the Edinburgh University Department of Psychology made the years I spent there as an undergraduate, post-graduate and staff member, most cordial and most stimulating.

TORONTO, 1970. M.P. Cowles

ABSTRACT

The study is divided into five chapters. Chapter I presents a survey of the concept of activation, a general process which emphasises the intensity rather than the direction of behaviour. The broad nature of the concept is discussed and its physiological background is described, highlighting the difficulties of maintaining the unidimensional approach. The inverted U curve hypothesis is described and the relationship between 'peripheral' physiological indices and performance levels against a background of reticular formation function is examined. Some of the evidence pointing to a two-dimensional approach to activation, one dimension based upon the reticular formation function, the other on the limbic system, is examined. Recent evidence from the study of sleep is discussed in relation to activation.

Chapter II presents a survey of the indices of activation examined in the study and a brief reference to other possible indices. The neurophysiological basis and methods of measurement of the variables is described. A selection of previous studies which have examined these variables, particularly in relation to performance, is presented for 1. electrodermal variables, 2. muscle tension, 3. eyeblink rate, 4. figure reversal rate, 5. heart rate, 6. respiration, 7. E and N scale scores.

Chapter III reviews attempts which have been made to quantify these physiological variables, discussing the problem of which units of measurement to employ and which statistical techniques to use.

Chapter IV describes a series of experiments in which the chosen physiological and personality variables and scores on a set of performance tasks were examined. The tasks were recognition threshold, reaction time, paired associate learning and tracking. Factor analysis was used to examine inter-relationships and multiple correlation analysis was chosen to examine the utility of the physiological and personality variables as predictors of performance. Some modest but apparently reliable relationships were observed between the physiological variables. Three of the four tasks (reaction time, tracking and paired associate learning) were related. Basal level of skin conductance and N scale score appeared to be the best predictors of performance, the latter on tasks with a learning component. GSR latency merits further study.

Chapter V discusses the results of the experiments. The tasks used are examined as candidates for criteria of activation and their relationship with the physiological indices described in more detail. The conditions under which relationships between physiological variables might be found are discussed. The utility of GSR latency is examined and speculation on its physiological basis is offered.

A list of references is given.

In a set of appendices, the data extracted from the physiological records, inventory and performance scores is given. A selection of frequency distributions of this data is shown. The word lists and inventory used are given and examples of chart records presented.

I THE CHANGING CONCEPT OF ACTIVATION

The behavioural states of the organism described by such terms as alertness and inattention, waking and sleeping, tension and relaxation, excitement and calm, have been drawn together under a single rubric called activation or arousal. Changes between these extreme states can be conceived of as reflecting variations in activation or arousal level. Differences in autonomic, somatic and neural functions between the extremes, differences noted both in casual observation and in carefully controlled experiments employing highly sophisticated apparatus and recording techniques, have led to the suggestion that measures of these functions may be employed to represent all levels of activation, on a continuous scale, from very low to very high. The bipolar nature of the behavioural descriptions tends to favour a dimensional approach, and the concept has, until recently, been one of a single all-embracing dimension. Much thoughtful and vigorous effort has been expended in refining the theory and testing it experimentally. From the start, the results of neurophysiological research have been used to add weight to the concept and to help to examine the theory. Recent experimental psychological and neurophysiological findings suggest that our ideas need to be and indeed are being revised.

The notion of a general energising process, an

intervening variable which emphasises the intensity rather than the direction of behaviour, has been seen in a variety of guises in the history of psychology. Malmo (1959), has developed the process with the introduction of the idea of internal activation or arousal, integrating within his theory the concepts of general drive, (Hull, 1943), behavioural activation, (Duffy, 1951, 1957, 1962), and reticular formation function. Other workers have also contributed to the development of the concept, notably Freeman, (1948), with his work on the 'energetics of behaviour', who examines the process in terms of the degree of energy mobilisation within the organism, a concept elaborated upon by Duffy in her examination of the organism's degree of 'excitation'. The theory of the 'Central Motive State' presented by Morgan (1957) as well as early concepts such as Freudian 'libido' and 'tension' (Lewin, 1938) can also be accommodated within the process, together with 'emotions', 'motives' and 'drives'. The all-embracing, omnibus nature of the concept of energisation has, unfortunately, affected the concept of activation and this has led some workers into over-eager attempts to equate motivation with a single physiological measure (e.g., Coules and Avery, 1966). The introduction of physiological measures into research on the 'intensive' aspects of behaviour is an attempt to measure the internal neurophysiological processes involved, since the level of activation and energisation is not necessarily synonymous with the force of overt behaviour, but again, as Jerison (1967) has noted, the very broad nature of the concept has made

precise measures and predictions based upon physiological indices very hard to attain because it can explain almost any empirical finding.

Hebb (1955), in a key paper, traces the course of the psychologist's 'neurologising' in relation to drive, highlighting the difficulties of the classical S-R approach which assumed a relatively inactive organism aroused to activity by specific drives, hunger, sexual excitement and so on. Later conceptualisation emphasised the energy and activity of the nervous system, the classical drive states being the channellers and directors of the energy of response originating from the metabolic processes of the organism. Sensory deprivation experiments (e.g., Bexton, Heron, and Scott, 1954) have shown that human beings demonstrate to a greater rather than a lesser degree a need for stimulation, and Butler's (1953) work with monkeys has demonstrated the reinforcing properties of stimulation. The notion of activation as energy mobilisation is attractive, but the discovery of Moruzzi and Magoun (1949) of the arousal function of the reticular formation of the brain stem has probably given the greatest impetus to work on the physiology of activation. These workers showed, among other findings, that stimulation of parts of the mid-brain reticular formation of animals in a barbiturate-induced sleep, produced a desynchronised 'awake' EEG pattern, the interpretation being that the reticular formation included a structure that diffusely aroused the organism and kept it in an alert state. Sleep then, at the low end of any hypothesised activation

dimension, could be thought of as a passive process produced by inactivity in the structure called the reticular activating system. This system is one of the two main pathways by which sensory impulses travel to the cerebral cortex. This route is diffuse and indirect, the thalamus providing the direct pathway. The main point is that increasing sensory stimulation leads to high arousal via the system and reduced sensory input by reducing activity in the system leads to low arousal and eventually, sleep. The traffic however, is not all one-way, impulses from the cortex affecting the system and arousing it. Lindsley (1960) has reviewed the evidence which supports this view of reticular formation function. In particular, Starzl, Taylor and Magoun (1951) have shown that activity in the reticular formation is maintained by collaterals of the primary sensory pathways.

Lindsley (1951) published a paper which gave great impetus to researches into activation theory and the investigation of suitable methods of measurement of activation level. Over the next fifteen years or so, the general theoretical approach has been the 'inverted U Hypothesis' developed most adequately and vigorously by Malmo (1958, 1959). Generalised arousal develops from all motivational operations of the organism if appropriate environmental stimulation is present. The central active state of arousal is mediated by the reticular formation which in turn, affects 'peripheral' physiological phenomena, electrodermal indices, muscle tension, circulation and so on. In general, increasing activation leads to more intense overt

behaviour, but at the higher levels, for example under great deprivation, the overt responses usually associated with the drive may not be seen. The experimental paradigm for the inverted U relationship between activation level and performance is as follows: As activation level varies from relatively low to moderate to relatively high, expected performance level varies from low to optimal to low again. Many workers maintain that the measures of activation level have meaning only in relative terms, that is, the level of activation which is termed 'moderate' and is optimal for one task and one individual is not to be compared directly with the level of activation for a different task or for a different individual. Most of the experimental evidence has been obtained from intra-individual studies in which attempts have been made to vary activation level by sleep deprivation, reward and punishment, stress induction, setting standards of performance and so on, and at the same time measuring performance and recording one or more of the possible physiological indices of activation. More details of many of these studies are given in Chapter II together with evidence from inter-individual studies. In the latter case an attempt is made to keep the factors which may affect activation level constant for all the subjects, and to relate performance measures to simultaneously recorded physiological indices. Unfortunately, the evidence is by no means overwhelming and is sometimes unconvincing. The concept of activation as a unidimensional all-embracing factor begins to appear unsatisfactory however, not because of the relative paucity of

the experimental evidence, but because of certain facts which it either ignores or deals with inadequately.

Duffy (1962) recognises that there must be some interaction between degree and direction of behaviour when she says, "the level of arousal depends in part upon responses to cues, and the ability to respond to cues, and to inhibit and co-ordinate reactions, depends in part upon the level of arousal." This interaction was used by Hebb (1955) in presenting his view of optimal arousal level, "Physiologically we may assume that cortical synaptic function is facilitated by the diffuse bombardment of the arousal system. When this bombardment is at a low level an increase will tend to strengthen or maintain the concurrent cortical activity; when arousal or drive is at a low level, that is, a response that produces increased stimulation and greater arousal will tend to be repeated. . . But when arousal is at a high level, . . . the greater bombardment may interfere with the delicate adjustments involved in cue function perhaps by facilitating irrelevant responses . . . Thus there will be an optimal level of arousal for effective behaviour . . ." Hebb also recognises that the arousal system may not be a single homogeneous system, citing in particular the work of Olds and Milner (1954), which reports on the 'rewarding' effects of intra-cranial stimulation (see below). Malmo identifies arousal with motivation. This seems to suggest that no motives exist until there is stimulation (i.e., until a stimulus is presented). As Miller (1965) notes, "Since it is also true that overt responses do not

occur until the stimulus is presented, . . . the critical distinction between motivation and behaviour is lost". Miller reviews other evidence which questions the equation of arousal and motivation and casts doubt on the notion of arousal as a simple unitary state.

The difficulties of activation theory have been reviewed by Lacey (1966) who points out that measures and manifestations of activation level defined in various ways, subjective (by rating scales for example), cortical (EEG desynchronisation), autonomic (electrocardiograms, electrodermal measurements etc.) may occur independently of each other. The intra-individual patterning of activation responses, (Lacey and Lacey, 1958), in addition to making the task of measuring activation level across individuals extremely difficult, does not make arousal look like a unitary phenomenon unless the unlikely supposition that these individual patterns all have exactly the same effect on behaviour is made. Intercorrelation between physiological measures of arousal reported by Ax (1953) produced an average figure of .12. Schnore (1959) in a study of individual patterns of physiological activity reports results which support the contention that measurements and comparisons within subjects are superior to between subject investigations. However, an interesting fact emerges from this study, ". . . a point that, curiously enough, appears to have been overlooked by some writers. Despite his idiosyncratic pattern, an individual placed in an arousing situation will, according to the results of the present study, probably

show a general increase in most physiological functions". The emphasis in the studies from the McGill laboratory is on this intra-individual approach and Berry (1962a) asserts that Malmo's insistence on within-task and within-individual comparisons, "is a conservative approach unquestionably motivated by experience and by technical considerations". Berry believes that, "Although the inter-individual relation has not been established neither has it been disproved".

Hume (1968) reported on a factor analytic study designed to evaluate the assumed unitary nature of the arousal concept. No general factor of arousal was found. Three groups of subjects, normals, neurotics, and psychotics, were used and Hume found that different components of arousal tended to have different relations with each other in the different groups. This study has been criticised on the grounds of inadequacy of design for factor analytic purposes, but the very fact that it was done demonstrates the dissatisfaction with the unidimensional theory.

Corteen (1965) and Corteen and Blackman (1965) have produced evidence for a two dimensional approach to the activation concept, evidence which is being supported by recent work by Van Olst, Orlebeke and Fokkema (1967). Corteen's work indicates that basal skin conductance and galvanic skin response (GSR) are respectively, measures of long term and short term activation. In marshalling physiological evidence for his theory Corteen cites the work of Jasper (1958) who, in referring to localisation of function in the non-specific reticulo-thalamic system, mentions

the "rapid, short-lasting or phasic activation of the cortex in contrast with the slower, longer-lasting tonic activation which depends on the more caudal portions of the reticular system". Corteen and Blackman's experiment demonstrates a relationship between mean GSR and sensory discrimination. Their work "indicates that GSR can best be thought of as a peripheral manifestation of a sensitizing or orienting reponse which is basically facilitated by a cortically controlled centre in the rostral part of the non-specific reticulo-thalamic system". The theory draws on the work of Deutsch (1960) and Deutsch and Deutsch (1963) in discussing the possible interaction between these two aspects of activation, an interaction between some sort of cortical 'pre-awareness' weighting of incoming stimuli in a specific alerting system and general level of arousal. A similar position is taken by Lindsley (1961) who favours at least a bimodal theory of arousal. On the one hand, some sort of general arousing mechanism capable of arousing from sleep or bringing the wakeful organism to a state of general attention; on the other hand a specific attention mechanism "based on the neurophysiologically demonstrated interactions within the reticular system and on various sensory relays which provide the mechanism for differential response to environmental stimuli, with suppression or ignoring of some and heightening of attention for others".

In his 1959 paper, Malmo, while believing that activation level is a product of multiple factors, on balance stands by the view of the ascending reticular activating system (ARAS)

as a "unitary intensity-mediating mechanism", though he recognises that there are some difficulties in maintaining this position. Malmo and Bélanger (1967) examine activation theory in the light of more recent work. Experimental evidence which they review reminds us "that performance is multiply determined". They recognise that although the 'arousal system' is important, "there are behavioural changes that evidently are chiefly mediated by changes within the 'cue system', with little or no change in level of activity within the 'arousal system'". That the ARAS neurophysiological model of the 'arousal system' needs revision is indicated by the report of Feldman and Waller (1962), who say, ". . (a). . behavioural arousal is lost following posterior hypothalamic lesions despite the functional integrity of an ascending pathway from the midbrain reticular formation which can provide ECG (electrocorticographic) desynchronisation; (b). . slow ECG activity is the dominant pattern following lesions of the midbrain reticular formation, despite the integrity of a conducting pathway (through the hypothalamus) which can mediate (behavioural) arousal and alert attentive behaviour. This leads to the conclusion that although behavioural arousal requires the integrity of the posterior hypothalamic region, induced ECG activation is not critically dependent on pathways funnelling through this region". Malmo and Bélanger agree that this finding emphasises the importance of the hypothalamus in the 'arousal system'. We shall return to this later.

Any account of activation must include and take note of

our knowledge of the state of sleep, which, at any rate as far as overt behaviour is concerned, can be thought of as the low point of any activation scale. Indeed, a specialised definition of arousal is, as we have seen, in terms of the desynchronised low voltage fast activity of the EEG as opposed to the synchronised high voltage slow wave form of sleep. Our views of sleep and EEG activity during sleep have changed. Bremer's work in 1935 (reviewed 1954) with the 'encéphale isolé' preparation (a complete transection between the spinal cord and the medulla), and the 'cerveau isolé' preparation (transection between midbrain and diencephalon) showed that in the former case a desynchronised 'awake' EEG could be shown and in the latter the synchronised EEG similar to that seen in sleep in normal subjects could be seen. The conclusion was that normal waking is maintained by afferent input. Reduction of sensory input produced sleep by a passive deafferentation process. The 'awake' EEG pattern, Bremer believed, was maintained by trigeminal and vestibular influences. The work of Moruzzi and Magoun (op. cit.) emphasised the importance of the reticular formation. The synchronised pattern of the 'cerveau isolé' was due to the severance of the reticular formation from the cerebrum and the desynchronised pattern of the 'encéphale isolé', where spinal inputs are of course absent, was possible because the reticular formation could still bombard the cortex. Again the passive nature of sleep, when reduced sensory input brings about inactivity in the reticular formation, is brought out.

Routtenberg (1966), has reviewed the more recent data on sleep and its relationship to EEG patterns. The main points will be set down here. The periods of rapid eye movements (REM) seen during sleep (Aserinsky and Kleitman, 1955), have been shown by Dement and Kleitman (1957a), to be related to periods in which the subject was very likely dreaming. Dement and Kleitman (1957b) have also shown that during a REM stage the EEG pattern was the desynchronised 'awake' variety. Dement (1958) discovered progressive synchronisation of the EEG as a warm, well-fed and sleep-deprived cat was allowed to sleep. Following complete synchronisation, desynchronised patterns and REM were seen (Stage 1 REM). This was followed by a progressively more synchronised pattern, (Stages 2, 3, and 4), then Stage 1 REM again and so on. It was more difficult to awaken the animal during Stage 1 REM sleep than at any other time, though this is when the so-called 'awake' EEG pattern is seen. Two hypotheses can be presented. First, that Stage 1 REM sleep was a light stage of sleep and that the animal was difficult to awaken because it was distracted by its dream and secondly that Stage 1 REM in fact was a deeper stage of sleep than synchronised EEG pattern sleep. Jouvet favours the latter view (reviewed 1962, 1963), and has elaborated on and extended our ideas on the mechanisms which may be involved in sleep. The two main stage of sleep are called 'slow' and 'fast' or 'paradoxical' sleep. The former is marked by slow EEG waves (S-SW), respiratory movements are regular and electromyogram potentials are present. 'Fast' sleep is marked

by low voltage fast EEG activity (S-LVF) similar to that seen in the waking state, marked atonia is observed and the neck EMG is flattened. In cats, twitching of the tail and ears is seen, respiratory movements are irregular and the cardiac cycle may show either a distinct acceleration or deceleration compared with S-SW. The threshold of arousing by either midbrain reticular or peripheral sensory stimulation is appreciably raised during S-LVF. Jouvet's ablation and lesion studies have suggested that S-SW is brought about by cortical influences and that sleep with desynchronised EEG or 'rhombencephalic' sleep (S-LVF) is triggered by activity in the pontine reticular formation (more precisely the n. reticularis pontis caudalis or RPC). The evidence seems to be against the notion that the midbrain reticular formation mediates the desynchronisation seen during S-LVF, for lesions in the dorsal tegmentum which abolish the EEG arousal response to nociceptive stimuli do not abolish the desynchronising action seen during S-LVF. Lesions in the limbic midbrain circuit described by Nauta (1958) reduce or eliminate S-LVF. Jouvet attempts to distinguish between EEG desynchronisation in arousal and S-LVF desynchronisation. The evidence suggests that S-LVF is a deeper stage than S-SW and that sleep is not a passive deafferentation process but primarily an active process. Hess (1957) and Jouvet (1962) have shown that stimulation of particular brain loci can induce sleep, which provides evidence for the existence of 'sleep-promoting' centres.

Routtenberg (1966) in reviewing and discussing this

recent evidence, postulates two anatomically distinct desynchronising systems. Arousal System I is closely related to that system described by Moruzzi and Magoun. Arousal System II is part of the limbic midbrain system described by Nauta (1958). Cortical EEG desynchronisation does not distinguish between the two systems. Routtenberg suggests that the evidence shows that System I desynchronisation is associated with desynchronised electrical activity in the hippocampus and System II desynchronisation with hippocampal theta activity (4-7 cycle per second waves), and further that hippocampal theta tends to dampen the activity of System I. Grastyan (1959) presents the view that hippocampal theta activity represents an inhibition of the orienting reflex to novel stimuli. Routtenberg's assumption is that the S-LVF mechanism (RPC) inhibits the synchronising mechanism (tentatively identified with n. tractus solitarius). This removes the inhibition from System I and System II and permits the latter's activity, which appears as neo-cortical desynchronised EEG activity and hippocampal theta. The assumption that RPC directly or indirectly inhibits neck muscle EMG, vasoconstrictor tone, sudomotor activity and spinal reflexes completes the description of S-LVF - 'paradoxical sleep'.

The neurophysiological evidence is far from being complete but it does seem to be apparent that the view of a single unified reticular formation, active during waking and inactive during sleep is inadequate to account for all the data and that the desynchronised EEG, the so-called 'arousal pattern',

may represent high arousal, moderate arousal or deep sleep.

Continuing with this theory Routtenberg (1968) re-examines the physiological evidence and suggests behavioural comparisons between Arousal System I and Arousal System II. Routtenberg tries to show that "Arousal System I is predominantly concerned with drive or organisation for a response . . . in a general sense Arousal System I must be active for the production and the selection of the appropriate responses; . . . response occurrence whether approach or withdrawal is more probable when Arousal System I is active and less probable when Arousal System I is inactive". Glickman and Schiff (1967) also hold the view that the midbrain reticular formation is important in the integration of response mechanisms necessary for reinforcement. The view of the role of Arousal System II in behaviour is based on the work of Olds and Milner (1954) on the phenomenon of self-stimulation. Arousal System II is thought of as a reward system. A great deal of work has been done on the effects of self-stimulation and the interplay of effects from the various brain loci is not entirely clear. The effects of self-stimulation on 'peripheral' physiological phenomena too, is not fully understood but Perez-Cruet, Black and Brady (1963), for example, have shown that septal area self-stimulation reduces heart rate and hypothalamic self-stimulation increases heart rate. In summarising his proposals Routtenberg suggests that hypothalamic activity activates Arousal System I and that hypothalamic stimulation is rewarding because of both Arousal System I and Arousal System II

activation. Septal area activity dampens Arousal System I activity and septal stimulation is rewarding because of Arousal System I suppression and Arousal System II activation. Though Deutsch (1960) does not distinguish between rewarding effects in the two regions, he does, as Routtenberg points out, propose a very similar view. Routtenberg also suggests that the rewarding effects of both suppression and excitation of Arousal System I fits in with an optimal level of arousal theory. Hebb (1966), for example, suggests that high to medium or low to medium changes in reticular activity are reward conditions. In general, the suggestion that these two systems are operating is not at variance with the notion of a longer term activation reflecting the overall efficiency of an individual organism and a short term system which is much more dependent upon the immediate circumstances and stimulus input. Both systems are active and in general they are in equilibrium. Precisely what the physiological effects of an imbalance in the systems are is difficult to ascertain though stimulation studies are throwing some light on the problem. One difficulty lies in defining precisely the anatomical areas concerned in the two hypothesised systems - if indeed this is possible - for example, as Routtenberg has indicated, "the term 'reticular formation' often represents a wide variety of points in the midbrain and pons that would represent components of both Arousal System I and Arousal System II". It seems highly likely that activity in two systems such as these will have different effects upon 'peripheral' physiological activity depending upon which

system is most active and which index is being studied at the time.

It is the aim of the present study to examine once again a selection of 'peripheral' physiological indices with respect to their validity as indices of level of activation, their reliability and possible inter-relationships. If reliable inter-individual comparisons are to be obtained then it is essential from what has been discussed above that the conditions under which the measures are taken must be kept the same for all subjects, that there should be the minimum variation in environmental stimuli and that as far as this is possible the situation should be perceived in much the same way by all the subjects. Clearly experiments in which stress is induced in the subjects are not likely to achieve these conditions. For example in Ax's (1953) study referred to above, which involved inducing anger and fear in the subjects, great care was taken to ensure that the procedures were made as similar as possible but, as Ax reports, "Examples of fear reactions were clearly genuine. One woman kept pleading, 'Please take the wires off. Oh! Please help me'. Another said during the interview that she had prayed to be spared during the fear episode. A man said, 'Well, everybody has to go sometime. I thought this might be my time'. " The subjects' perceptions of the situation and their reactions to it while they all show 'fear' are obviously very different in degree and, assuming that activatation is indeed multiply determined, these differences might be reflected by differential activity in the various systems and

physiological responses. It would appear therefore that in the initial stages, every effort must be made to allow the subject to become used to the situation, that measures should be taken on more than one occasion and that simple procedures well within the capacity of the subject sample should be used in an attempt to achieve uniformity as far as possible.

The problem of linking the peripheral measures with central systems remains. Nevertheless, if the results of researches into these systems and into peripheral physiological and psychological response measures appear to point in the same direction then the bridge-building between physiology and psychology can continue with gains to both disciplines.

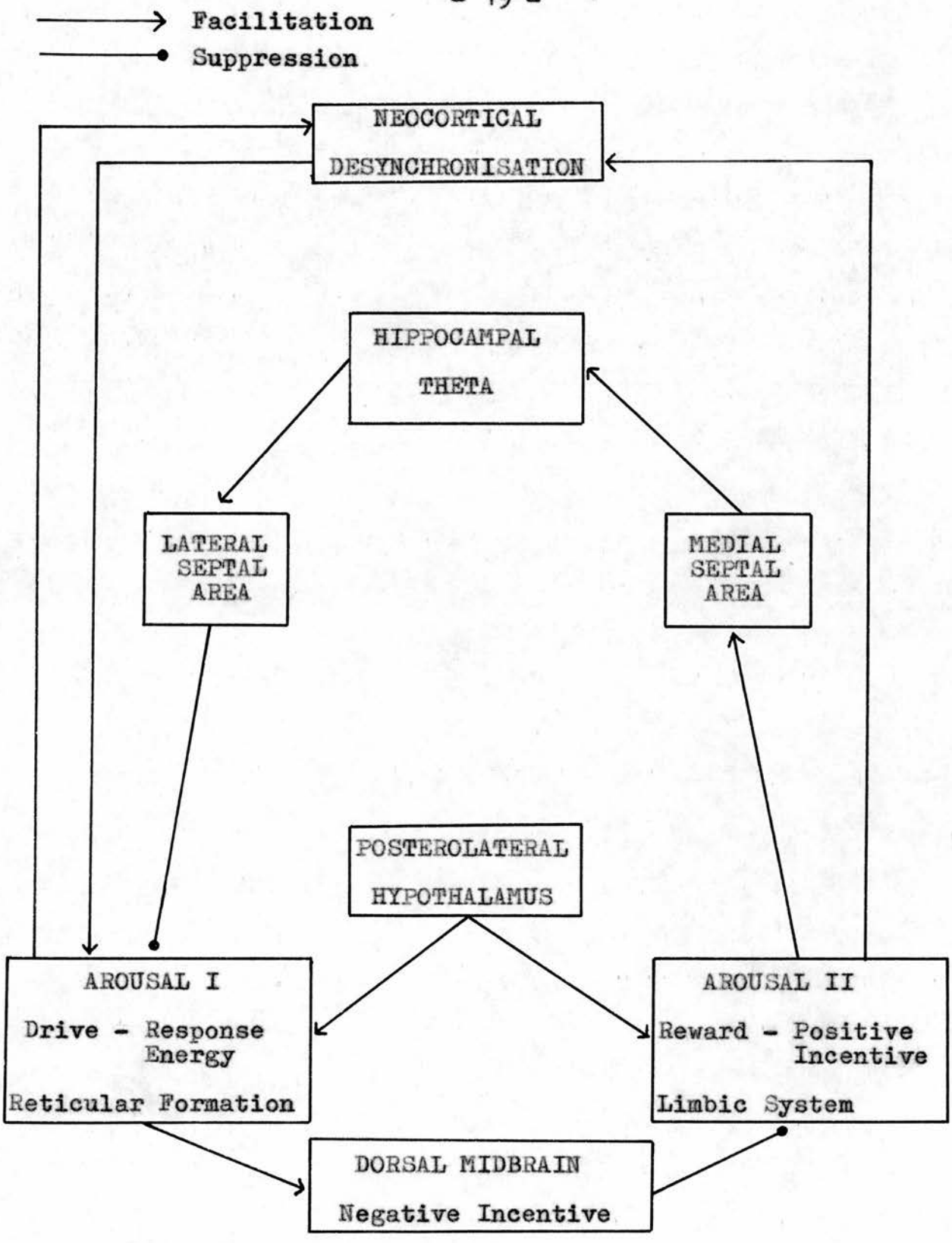

Figure 1 (after Routtenberg, 1968)

II INDICES OF ACTIVATION

The title of this section really only labels it and sets it in context, for the descriptions of the various physiological indices which follow do not adequately define 'activation'. It appears to be quite common for workers in this area to lump together as measures of arousal or activation a great variety of physiological phenomena and behavioural yardsticks which are assumed to affect or to be affected by it. The same measures sometimes purport to measure motivation, drive, stress level, vigilance, emotion, tension, anxiety, energy mobilisation, behavioural intensity and so on. This thesis is principally an account of an investigation of a selection of physiological indices, their inter-relationships and their relationships with a small selection of performance measures which have been adopted as criteria. The selection of the variables used was not entirely arbitrary, though it was of course closely governed by the availability of suitable apparatus and other facilities. All the variables used have been used in previous studies in the same, admittedly very wide, area, and a number of attempts have been made, with varying success, to fit them into the same general framework. The indices do not 'explain' activation any more than an account of electric shock intensities, taboo words, coloured lights and so on 'explains' the concept of a 'stimulus'.

Activation is now so broad a term that it cannot be so closely defined as to satisfy all or even most people interested in the area.

This chapter is concerned with an account of the variables used in the experiment, problems that have been found in recording them and some of the previous studies in which they have been used. It is not a comprehensive review of previous work for such a review would be far too lengthy and to some extent superfluous since many reviews are available and these are mentioned where appropriate. A brief mention of some of the possible variables which were not used in this study is also made. The problem of units of measurement is reserved for a separate section.

1. Electrodermal Activity

Manifestations of the electrical properties of the skin, particularly of the palmar skin, are perhaps the best known and certainly appear to be the most widely used indices of activation level. Two basic phenomena may first of all be distinguished - the galvanometer readings associated with the passage of a small electric current through the skin (the exosomatic method) first noted by Feré in 1888 and, the endosomatic skin potential reported by Tarchanoff in 1890, when he noticed that galvanometer deflections could be produced without the aid of an external current. It is now common to distinguish four basic electrical properties viz. basal level of skin resistance (or the reciprocal, conductance), short term changes in resistance referred to as galvanic

skin responses (GSR), skin potential level and changes in potential referred to as galvanic skin potentials (GSP) - the last two, of course, being the results of the Tarchanoff or endosomatic effect. In studies of arousal or activation, conductance rather than resistance units are used since conductance is thought to vary directly with activation level. It is important to note that palmar skin conductance appears to vary all the time and that basal level of conductance (BC) refers to an absolute level only at a given time and in a particular situation. In general however, changes in this basal level are slow and are easily distinguishable from the short-lasting rapid variations which we denote as GSR's. These latter are most easily evoked when the individual is subject to sudden stimulation; thus, a loud noise will cause a sharp increase in palmar skin conductance in 1 to 4 seconds and there will be an almost complete return to basal level in most cases in 10 to 30 seconds. In addition, many workers have noted the occurrence of GSR's in the absence of any observable external stimuli and these changes, dubbed 'spontaneous GSR's' may also have relevance as indices of activation.

Grings (1953) presents data which supports the most widely accepted view that a circuit with a condenser in parallel with a resistance and both of these in series with other resistive components simulates the skin impedance situation. Teorell (1953) includes among the characteristics of biological ionic membranes, conductive properties and that they give rise to potential differences across their structure. Martin and Venables (1966)

reviewihg work on electrodermal mechanisms conclude that there is "adequate evidence that sweat-gland activity contributes to basal resistance level, GSR and GSP, and in the case of basal resistance level other factors are also important". Wilcott (1962) suggests that the nonsudorific element of electrodermal activity is a function of the structural characteristics of the epidermis. We have then, two relevant membranes, one at the secretory portion of the sweat gland which gives rise to GSR's and GSP's and is partially responsible for basal resistance level and secondly the epidermal element responsible for the remaining part of the basal resistance level.

Wang (1957) and Martin and Venables (1966) review extensively the anatomical and physiological evidence which supports the notion of the primary importance of sweat gland activity in electrodermal phenomena. Tarchanoff favoured the sweat gland theory as opposed to the vasomotor reaction theory (favoured by Feré) and electrical changes in muscle, both of which have now been largely discounted. Endosomatic and exosomatic responses change together. Jeffress (1928) showed that their latent periods on stimulation in any one person are almost identical, and a stimulus which elicits a large increase in conductance most probably elicits a large change in potential. Lykken et al. (1968) have shown that within-subject correlations are high. Both phenomena appear to be the result of changes in the membrane permeability of cells in the skin. Darrow (1964) presents the rationale for treating GSR as conductance in a scheme which explains the wide

range of reactivity as a result of two different electrophysiological processes which occur at high and low levels of resistance and overlap in the middle. Lader and Montagu (1962) present the view that the initiating event in the response is the release of a chemical mediator (for example, acetyl choline) from the nerve endings of the effector organs which diffuses across the neuro-effector junction and produces a change in membrane permeability and a change in potential.

Richter and Whelan (1943) have shown by direct surgical approach that GSR depends upon an intact sympathetic chain and that direct stimulation of the post-ganglionic fibres will produce a GSR. Sourek (1965) has carried out extensive studies on normal subjects and on patients and shown the effects of various neural lesions on the potential response. The response disappears following the cutting of peripheral nerves, the lumbar or thoracic sympathicus and the cervical and thoracic spinal cord. Sourek also reports that resections of different parts of the cerebral hemispheres produced no major changes in skin potential responses. There is little data from human subjects on the nerve supply, and what is available presents some difficulties in interpretation. When sympathectomies are performed for the relief of Raynaud's phenomenon there are often atrophic skin changes and skin temperature is affected. Both endosomatic and exosomatic responses are affected by skin temperature (see for example, Yokota et al.(1959), Maulsby and Edelberg (1960), Scholander (1963), Wilcott (1963)).

Most of the studies on the innervation of electrodermal

mechanisms have been carried out on animals, particularly cats. Wang (1957, 1958) reviewing a large number of physiological studies, reaches the following conclusions, among others; the sensorimotor area of the cerebral cortex, the hypothalamus of the interbrain and midbrain are involved in the suprasegmental excitatory pathways of the reflex. The frontal lobe of the cerebral cortex, the caudate nucleus of the striate body, the anterior lobe of the cerebellum, and the ventromedial reticular formation of the hindbrain are involved in the suprasegmental inhibitory pathways of the reflex. These findings have been made by electrical stimulation and ablation studies. For example, Wang reports that in an animal decerebrated between the superior and inferior colliculi, the loss of the forebrain, the interbrain and rostral midbrain, removes all the supraspinal excitatory influences and leaves the inhibitory influence from the bulbar ventromedial reticular formation unchecked and dominant. Consequently GSR is completely inhibited. Now, if these inhibitory influences of the bulbar reticular system are removed either by anaesthetising it or by cutting the spinal cord, the GSR reappears. This work illustrates the most important role which the reticular formation plays in the regulation of the reflex. Martin and Venables (1966) point out that Wang's data do not refer to standing <u>levels</u> of either potential or resistance, and the importance which he places on the role of the reticular formation in the galvanic skin reflex applies

strictly to potential response only[1]. The point arising from Wang's work and the work of others which he reviews is that the facilitatory area is placed in the upper or rostral portion of the reticular formation of the brain stem. Jasper (1958) emphasises that it is the "thalamic and sub-thalamic portions of the reticular system which seem to mediate the rapid, short-lasting or phasic activation of the cortex, in contrast with the slower, longer-lasting tonic activation which depends upon the more caudal portions of the reticular system". Corteen and Blackman (1965) suggest that these areas may be thought of as a stimulus selection and facilitation centre, that this centre is activated by a warning or alerting stimulus and that GSR is a peripheral manifestation of the reaction to the alert.

Problems in the recording of electrodermal phenomena have been reviewed by Hume (1966) and by Venables and Martin (1967). Some of the points are listed here and more detailed studies cited:

1. Type of electrode and electrolyte; Floyd and Keele (1936), Lykken (1959), O'Connell, Tursky and Orne (1960), Ives and Janz (1961), Malmo (1961), Edelberg and Burch (1962), Miller (1968).
2. Electrode site; Grings (1953), Malmo (1958), Wilcott (1960).

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[1] Although in the main Wang did use a potential method he does on occasion take resistance readings e.g., P.299 of Part II of his review, "Recently we have stimulated the lumbar sympathetic chain of the cat and recorded successively the decrease in resistance and the change in potential thus induced in the same ipsilateral hind foot". He certainly views 'GSR' ≡ galvanic skin reflex as being registered either by a change in skin potential or a change in skin resistance.

3. AC or DC measurement; Grings (1953), Lykken (1959), Montagu (1964).
4. Constant current or constant voltage systems and current density; Lykken (1961), Malmo and Davis (1961), Edelberg and Burch (1962).
5. Skin and environmental temperature; see page 24 above.

Landis and De Wick (1929) and Landis (1932) have provided comprehensive reviews of the literature up to that time concerning the psychological correlates of the Galvanic Skin Response. They note that the most frequent claims are those which report a relationship between it and emotion. Later Landis and Hunt (1935) examining conscious correlates of GSR describe a "British school", based upon the work of Aveling (1929), "that attempts to correlate the GSR with conation". Their own conclusion is, "that this response is not associated to any marked degree with any one variety of stimulus or conscious state . . . we do not feel that there is any evidence which would justify our saying more than that the GSR is a fairly adequate indicator of 'change of direction of mental activity'". Over thirty years later the position is little changed, though many attempts have been made to measure the activity by quantifying the response. There appears to be a wide range of individual variability in the size of the response. Jones (1935) reviews studies which indicate that overt emotional response is associated with small conductance changes and covert responses with large changes. Jurko et al. (1952) studied normal, neurotic and schizophrenic subjects. He

reported that, 'energy mobilisation' in schizophrenics is expressed mainly overtly, in normals mainly covertly and that neurotics show a marked degree of both internal mobilisation and overt expression. Conductance change was taken as the measure of internal mobilisation.

A number of studies have examined the relationship of this measure with performance of all kinds.

Runquist and Ross (1959), classifying subjects as 'emotional' or 'non-emotional' on the basis of combined pulse rate changes and GSR's to a weak air puff presented prior to the experiment, found that the 'emotional' group performed at a higher level in an eyelid conditioning experiment.

Orne and Thackray (1967) describe an ingenious technique for averaging GSR across subjects to facilitate the detection of deception. This is one of many studies reported in which the use of GSR as a 'lie detector' is described.

Kleinsmith and Kaplan (1963) choosing words which differed in their "arousal value (as measured by galvanic skin response)" paired with single digits, found that 'low arousal' paired associates showed high immediate recall and rapid forgetting, 'high arousal' pairs showed low immediate recall and high permanent memory. Corteen (1969) obtained results which support the suggestion that the size of a response to an item is related positively to later recall of the item suggesting that "items associated with larger responses will produce more viable dynamic traces within the general context of the item set, thus leading

to the establishment of more effective permanent traces".

Courter et al. (1965) found that field independent subjects were able to discriminate between a tone to which they had been conditioned and unreinforced generalisation tones by the amplitude of their GSR's, significantly better than field dependent subjects, suggesting that "the stimulus generalisation gradient involves an interaction between the cognitive style of the organism and the impinging stimuli, not merely the quantitative physical characteristics of the stimuli".

Mandler and Mandler (1962) continuously monitored GSR and heart rate during a task which called for responses to non-anxiety arousing stimuli. Significant though relatively low consistencies in GSR and heart rate were shown for subjects across two different experiments. "Stimuli that show high associative frequency also evoke large conductance changes. However the GSR response appears to be more a function of relative idiosyncracy than of frequency; stimuli which produce less idiosyncratic and more common content show larger conductance changes."

Berlyne et al. (1963) found that subjects who were "extrinsically motivated i.e., those who were told to attend carefully because they would later undergo a recognition test" produced more frequent GSR's than subjects not so motivated. Some evidence was found which supported the notion that "more irregular" patterns, when used in stimuli, are more likely to evoke GSR's than "less irregular" patterns.

Basal level of skin conductance is the most popular

physiological index of arousal. There is an increasing amount of evidence which justifies its use in a variety of situations and in conjunction with a wide selection of performance tasks. Schlosberg (1954) asserts that "preoccupation with transient changes, the PGR (psychogalvanic reflex), has led to the general neglect of the slow drifts in absolute level of conductance, despite the fact that the absolute level is the most obvious correlate of general level of tension or activation . . .".

Stennet (1957) studied the relationship between performance on an auditory tracking task and two physiological arousal measures (skin conductance and electromyogram) under different incentive conditions. Results suggesting an inverted U relationship were obtained, the most efficient tracking performance being associated with intermediate EMG gradients and intermediate levels of palmar conductance.

Kling et al. (1959) and Kling and Schlosberg (1961) found that there were sharp increases in conductance at the start of a tracking task with both naive and practised subjects which seem "to indicate that each shift from one phase to another of even a familiar task is marked by an increase in activation or arousal".

Silverman et al. (1959) in a series of experiments noted the following results:- 1) There is an inverse relationship between the number of spontaneous or non-specific responses and basal resistance. 2) Using runs in a human centrifuge and drugs as stress and arousal inducers, the number of spontaneous GSR's increases in direct proportion as the individual is alerted or

aroused and response amplitude to specific stimuli increases with alerting but decreases when the subject is in a hyper-aroused state. 3) Basal resistance is inversely related to arousal. 4) When the GSR suggests moderate alerting, psycho-motor performance improves. 5) Responses to threshold stimuli relate directly to level of arousal as measured by the number of non-specifics.

Pinneo (1961) confirms the earlier results of Freeman (1938) and Freeman and Simpson (1938) that palmar conductance shows a regular increase as a function of increments in tension induced in the arm during auditory tracking.

Eason et al. (1965) found that skin conductance decreased during the course of a one hour vigil and that relative performance level manifested during two rates of signal presentation (fast and slow) was positively related to the relative magnitude of skin conductance. They interpret the results as indicating that activation level plays some part in vigilance.[1]

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[1] Adams and Boulter (1962) have evaluated the 'activationist hypothesis' of human vigilance which of course contends that environmental and internal sources of stimulation operating via the reticular system are the source of human alertness. They attempted to identify stimulus determinants of vigilance by manipulating certain stimuli (head and eye movements). No effect on vigilance decrement was observed. They believe that ". . absence of operational definitions for the type of stimuli as well as the characteristics of each stimulus class, gives the hypothesis little predictive capability for measures of motor behaviour". This view of activation theory is not uncommon and is forgiveable in view of the forceful presentation of the "stimulus determinant" views put forward by some writers. However, most would now agree that certain sensory aspects of signal detection have little to do with arousal level. Everyone (except individuals in a coma) will hear a loud report. In many vigilance tasks the signal is quite strong. However where the individual has to respond to this signal, then the accuracy, speed and intensity of his response are factors likely to be affected by his activation level.

Kleinsmith et al. (1963) tested the inverted U relationship between arousal (as measured by skin conductance) and learning (paired adjectives) reported by Berry (1962). A six-minute recall group gave results which suggested an inverted U relationship between recall and arousal level ($r = .54$ $p < .005$).

Ryan (1962) in one of the few inter-individual studies carried out suggests that if one attempts to keep the "factors affecting level of arousal" constant, i.e., no differing incentives, stress conditions and so on, then subjects with "higher levels of arousal should have superior performance to groups with lower levels". Results from an experiment in which subjects were required to balance themselves on a pivoted platform, skin conductance being measured simultaneously, support this suggestion.

The work of Corteen and Blackman (1965) and Corteen (1967) has been mentioned in Chapter I in relation to Corteen's two-dimensional activation hypothesis. The 1965 study was designed to investigate individual differences in sensory discrimination (critical fusion frequency, two-point threshold and discrimination of a pure tone against a white noise background) and to compare these differences with differences in both basal conductance level and mean GSR (defined as mean log change in conductance) elicited by a list of twenty words. Unfortunately the results relating to basal conductance level do not appear to have been reported but we may assume from the results of a pilot experiment that no significant relationship was found. Significant correlations were obtained between mean GSR and CFF and

two point threshold. No relationship between GSR and auditory discrimination was observed. This latter result is explained by assuming that the activating or orienting response (the peripheral manifestation of which is the GSR) affects the amount of activity in the auditory cortex facilitating both the tone and the white noise background so that there is no improvement in discrimination.

The later study by Corteen (1967) examines basal conductance level and its relation to three performance tasks - pursuit rotor tracking, a hand-eye co-ordination dotting task and simple reaction time. "Significant relationships were found with end-spurt and reminiscence on the pursuit rotor, overall performance on the dotting task and with the number of abnormally slow responses and optimum response speed in reaction time". No evidence of curvilinear relationships was obtained.

Cowles (1970) obtained results which confirmed the relationship between basal conductance and reaction time in a situation where reinforcement was not provided (by not giving knowledge of results). In a knowledge of results situation the relationship did not hold. This result contradicts Coules and Avery's (1966) finding of an association between fast reaction time and skin conductance in a knowledge of results situation. In this latter study however sample size was very small indeed ($n = 5$).

Basal conductance level and the various measures of response amplitude by no means exhaust the indices which may be

obtained from electrodermal events. GSR latency and duration have also been examined in certain conditions.

Wolfensberger and O'Connor (1967) examined GSR latency, duration and amplitude measures under a number of conditions of stimulus intensity duration and repetition - the stimulus source being a light in an otherwise light-proof room. Correlation between the measures was low. "Latencies did not differ significantly as a function of intelligence, stimulus duration or repetition, but high intensity stimuli did result in shorter latencies ($p = .01$)". The writers conclude that GSR duration might replace amplitude as a useful measure since it was more sensitive to changes in all three stimulus dimensions and that latency, although less variable than the other measures, "appears to be of little utility".

On the other hand, Surwillo (1968) states, "Available data reveals that there is considerable variation in latency of the GSR, both between individuals and within the same individual from one moment to another". In a study which examined reaction times to tone stimuli which also served as a GSR stimulus, a low positive but insignificant correlation was found between reaction time and GSR latency. When subjects "were required to direct greater attention to the stimulus that called for a voluntary response, GSR latency showed a significant decrease". However another experiment showed that although reaction time decreased significantly when subjects were asked to try harder GSR latency was unchanged. "Latency of the GSR is not related to how hard S

tries to give a quick (voluntary) response". Surwillo suggests that we might take shorter GSR latencies to indicate increasing autonomic arousal.

2. Muscle Tension

Although the concept of muscle tension is one about which there has been considerable confusion and ambiguity, for definitions of the term vary greatly (Block, 1936), most workers now define and use the concept in terms of the electrical changes which accompany activity in muscle; the record of these changes being called the electromyogram (EMG). Davis (1942) reviewed the concept of muscle tension noting that its definition as a physiological mechanism was not clearly decided. One way of separating the types of tension measured is by classification of the recording method. Davis suggests six broad groups: 1) those applying mechanical external forces and recording resistance to movement offered by limb and muscle; 2) those recording slight movements of parts of the body; 3) those eliciting reflex responses; 4) those requiring the performance of voluntary responses; 5) those recording electrical properties of the skin[1]; 6) those recording the electrical properties of muscles.

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[1] Although the view of Sidis (1910) that electrodermal phenomena originate in muscles is now known not to be the case a number of studies e.g., White (1930), Freeman and Simpson (1938), have shown that induced muscle tension tends to vary inversely with skin resistance and Balshan (1962) and Eason, Beardshall and Jaffee (1965) among others show that conductance levels and EMG are related.

Methods of recording EMG and of quantifying the data also vary widely, but methods involving some form of integration technique are the most favoured. Disagreement also exists regarding the muscle groups from which recordings should be taken, although most workers take simultaneous or near simultaneous recordings from a number of sites. Data obtained in this way varies in the amount of intercorrelation obtained between the various muscle groups sampled and the question as to whether a general factor of muscle tension exists then arises. Wenger (1943) and Balshan (1962) report the existence of a general factor.

Postural adjustment producing tonic contraction and voluntary movement producing rapid phasic contractions can both be recorded by picking up the large electrical potentials thus produced by either surface or needle electrodes. The potential field detected by surface electrodes is produced by local currents which flow between the resting and depolarised regions of the muscle fibre surface. The muscle cell membrane has a potential difference of 50 to 100 mv. across its surface - the inside being negative. Nerve impulses in the motor nerve reach the muscle end-plate on the muscle surface and then spread over the membrane as action potential. There is temporary reversal of the polarisation to a value of 30 to 40 mv. negative outside the membrane. The surface depolarisation triggers off the fibre's contractile mechanisms, (Hodgkin, 1951, Lippold, 1967). In order to pick up potentials from a single muscle fibre a near-microscopic intramuscular electrode and D-C amplifying system is necessary. In

this way the long-lasting after-potentials can be recorded. A similar electrode is needed to record muscle action potential spikes, although in this case A-C amplifiers would do. However, when potentials from a whole muscle or group of muscles need to be recorded, then surface or subcutaneous electrodes are necessary. An A-C amplifying system may be used because when many fibres are firing repeatedly and asynchronously, then the after-potentials tend to cancel each other out but the rapidly occurring 'spikes' do not tend to cancel each other out. As the muscle becomes more active the pattern becomes coarser and of higher amplitude, (Davis, 1959).

When muscle tension is being studied it is the whole muscle or indeed a muscle group that is of interest and, as Lindsley (1951) points out, the ability to survey more of the muscle activity is desirable in the study of muscle tension associated with emotional reactions.

Davis (1959) discusses a number of possible electrodes and the principles of electrode placement pointing out that anatomy of the muscle including both location and depth of tissue, electrode spacing, separation of activity from neighbouring muscles and orientation of the vector of activity of the muscle are all important in deciding on a suitable technique. Davis gives details of a number of standard electrode placements. Precise placing of electrodes is important to ensure repeatability and comparability between measurements taken at different times, for Lippold (1967) reports an observation that a lateral shift of

only half a centimetre of the distal electrode produced a 60% difference in integrated EMG level for a given tension, recorded from the triceps muscle. More than one muscle group has to be sampled in muscle tension work because as Lindsley (1951) noted "postural factors and shifting body movements can produce differential degrees of contraction in the various muscle groups". Balshan (1962) showed that of sixteen muscle groups studied, fourteen had loadings on a general factor of muscle tension, the ones which showed very little or no relationship (right sternomastoid and frontalis) being muscles which are very difficult to relax. Basmajian (1959) notes that the records obtained from different muscles differ to some extent, and apart from functional differences in muscles the cause of this is also to be found in differing numbers and arrangements of muscle fibres and their varying static lengths. Lippold (1967) notes that muscles concerned with the maintenance of posture tend to exhibit oscillation at about eight to ten cycles per second.

Much of the energy associated with muscle potential is at frequencies too high (above approx. 100 cycles/sec.) to be recorded by the usual ink-writing pen recorders. The ideal recorder for EMG therefore should be mirror or string galvanometer types or a cathode ray oscillograph which of course respond to high frequencies. The recording material used however is expensive - film or ultra-violet sensitive paper - and direct viewing of the record as it progresses is not possible. Ink-writing pen recorders are usually employed, often with an

electronic-integrator system which produces a secondary record which includes information obtained from the higher frequency ranges which the mechanical characteristics of the ink-pen would exclude from the primary record. Several integrator systems are available ranging from the simple but effective photo-electric method for integration of the primary record described by Eason and White (1959) to sophisticated electronic devices many of which are commercially available.

The relationship of muscular tension to activation has been frequently studied and many attempts made to relate this physiological index to performance on a wide range of tasks. A theory often proposed and which has been supported for a number of years (for example, Duffy (1941), Fitts and Sieger (1953), Hebb, (1955)) is that muscle tension produces or reflects a state of heightened activity in the cerebral cortex or possibly in the organism as a whole. On the most superficial level, the clumsiness of the unskilled or distracted person contrasted with the deftness of the expert and attentive, often seems to be associated with a higher level of muscular activity in the former. At the other end of the spectrum, the slowness, the error, of the sleepy or very relaxed person seems to be associated with a low level of muscle tension. Many attempts have been made to show that activation level as reflected by muscle tension when either too high or too low will have deleterious effects upon performance. There is a strong suggestion that there is no general effect of an increment in muscle tension and that in fact, the effect of

muscular tension depends upon what produces it.

Woodworth and Schlosberg (1954) have suggested that muscle tension may possibly be a reliable and valid index of activation level and Schlosberg (1954) further suggests that 'effort' may in some sense be thought of as representing activation. It follows that since muscle tension level might be thought of as indicative of the amount of effort a person puts into a task, we may have here an index of arousal.

Eason and White (1961) whilst noting that precise relationships have not been specified cite a number of studies which "support the proposition that tension level is affected by the amount of effort one puts into the performance of 'non-physical' tasks, or tasks in which the physical aspects are relatively insignificant", including the work of Jacobson (1938), Davis (1938, 1939) and a number of studies from McGill University. Bartoshuk (1955b) in a study which examined EMG gradients during mirror tracing produced results which support the hypothesis that "gradient slope is a direct function of strength of motivation to perform a given task". The speed and accuracy of task performance was here considered to be a direct function of the motivation to perform the task. In support of this assumption Bartoshuk mentions studies which have shown that EMG gradient slope is related to reported interest in a task and to the magnitude of incentives offered for good performance. In particular, Surwillo's unpublished data showing that "degree of induced motivation (as inferred from the magnitude of incentives offered) was statistically related

to gradient slope" is mentioned. A previous study by Bartoshuk (1955a) which investigated the effects of interrupting the task on EMG gradients produced some support for the view that the gradients may reflect the strength of the subject's motivation to do the task. The psychological significance of EMG gradients is examined here within the framework of Lewinian tension systems. Interrupting a task with a particular goal leaves the tension system undischarged, a notion which is supported by the finding of Smith (1953) of the relatively greater maintenance of muscle tension after interruption than after task completion. Eason and White's (1961) study mentioned above, emphasises that 'effort' has both an arousal and a directional component and assumes that during task performance energy produced by the arousal reaction is directed towards some stimulus object or goal. One generalisation supported by their work is that it seems to be the factors which induce the tension which determine whether or not the tension will be beneficial or detrimental to task performance. "If, for example, the tension primarily reflects the amount of effort being directed to a particular task, it will probably be beneficial to the performance of that same task. If, however, the tension primarily reflects effort which is being directed to a second task, then it may be detrimental to the performance of the first". Davis (1956) summarises the results of a dozen experiments carried out at the USAF School of Aviation Medicine at Randolph AFB in Texas, and again a similar sort of generalisation emerges, "that there are patterns of response, detectable by electromyographic

recording which will facilitate or inhibit other responses according to their similarity".

Courts (1942) in a review of the relations between muscle tension and performance examines the two general topics of the effects of induced muscle tension (IMT) on performance and changes of muscle tension accompanying performance. In the case of IMT, a U-shaped relationship between it and learning seemed to be typical though in non-learning situations or in situations involving little learning, "the relationship of efficiency to level of tension is not so clear". Three possible explanations of the influence of dynamometer tension (suggested by Robinson (1934)) are given. 1) Dynamometer tension may bring about greater constancy of proprioceptive stimulation, which, in turn, may act as a stabiliser in holding constant extraneous stimuli; 2) the increased proprioceptive stimulation may have brought about a general increase in tension with resulting readiness to react in all muscle groups; 3) the increased proprioceptive stimulation raises the general level of excitement in the cortex, increasing the speed and accuracy of operation even of its more complex response patterns.

Courts states that, "It is generally agreed that continuous mental or muscular work is accompanied by an increase of muscular tension as measured in various ways over the level maintained during rest". The difference in level of activity is greater at the beginning of work and over succeeding sessions appears to become less with practice. However, some work seems

to show that there is no consistent relationship between work output and level of muscle action potential (MAP). In the case of maze learning, Daniel (1939) found that decreasing tension was associated with the elimination of errors while increasing tension accompanied increased speed of performance. Courts reports an experiment by Davis which attributes tension changes during reaction time foreperiods to 'set', saying that "sets are patterns of incipient muscular and glandular activity". The results of this experiment are interesting and show: "1) Muscle tension is greater during the foreperiod than during a rest period . . . ; 2) Reaction time is inversely related to the level of tension at the end of the foreperiod. When an irregular foreperiod is used, the highest tension and the shortest reaction time occur with a foreperiod of about average length; 3) Tension is higher and reaction time shorter when a fixed rather than a variable foreperiod is used".

Following Malmo's (1959) suggestion that inducing tension may be a way of varying activation level, and supported by the work of Freeman (1938) and Freeman and Simpson (1938) who showed a relationship between IMT and palmar conductance, Pinneo (1961) examined the relation between IMT, performance and a number of indices of activation (EEG,EKG,EMG and respiration). All the physiological data was "consistent in showing regular and continuous rise in level as a function of increments in tension induced in the right arm during tracking". Level of IMT was related to the EMG recorded from both active and passive muscle groups.

Pinneo considers that his results support the theory that proprioceptive return from IMT "produces generalised behavioural and physiological effects indirectly by increasing activity in the reticular activating system".

Pinneo points out that Meyer's (1953) explanation of the effects of IMT on performance - that they are the result of simultaneous responses occurring at the level of the motor cortex - "fails to consider the involvement of the reticular activating system and level of arousal in muscle tension phenomena".

Smock and Small (1962) report a curvilinear relationship between IMT and accuracy of form recognition in a tachistoscope task. Again the result can interpreted within an arousal framework in which central perceptual and peripheral motor processes are interdependent in regulating perceptual inputs and consequently behavioural efficiency.

Andreassi (1965) showed that manipulating IMT resulted in improved tachistoscopic perception. A linear relationship was not found however. In fact inducing one half maximum tension (measured by asking subjects to squeeze a dynamometer) resulted in the best performance "while levels of one quarter or three quarters did not affect performance beneficially or adversely as compared to the zero tension condition". These results can be interpreted within an activation concept, a possible explanation being "that peripheral and central mechanisms act

simultaneously to facilitate visual perception." [1]

Eason, Harter and Storm (1964) examined skin conductance, heart rate and neck and forearm EMG during nonsense syllable learning in different conditions of IMT. No significant correlation was obtained between members of any pair of the four variables. Although these findings are in agreement with those of Schnore (1959) they are based upon a very small sample of sixteen subjects. The fact that average scores for each subject plotted on a graph gave unique profiles emphasises these individual differences, though the average value for the correlation coefficients (0.12 and ranging from 0.28 to 0.04) might indicate some relationship. Nevertheless the same study showed some consistency in the variation of the physiological variables. Skin conductance, heart rate and neck tension decreased <u>across</u> trials, while forearm flexor level increased. It was when <u>within</u> trial changes were examined that the variables were found to vary in a

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[1] Fuster (1958) measured the reaction times of mohkeys in reaching for objects in a tachistoscopic device (the animals had previously been trained to discriminate between objects in order to obtain a reward), with and without stimulation of the brain stem reticular formation via an implanted electrode. Under the stimulation condition, mean reaction time was consistently reduced and choice performance (i.e., choosing the correct object for reward) was consistently improved. The conclusion is that reticular stimulation facilitates the neural processes involved in perception and that it is the central integrative processes which are primarily benefited rather than sensory input or motor output. Lindsley and Griffiths' (1958) work with cats, showing that reticular formation stimulation reduced two-flash threshold as indicated by evoked cortical potentials, also shows how cortical facilitation can be produced by reticular stimulation.

unique but systematic manner. Averaging the data across blocks of four trials revealed this systematic variation. The similarities and differences were interpreted "as differentially reflecting changes in the autonomic and somatic nervous systems during the course of the experiment" - emotional changes due to degree of apprehension, maintenance of a specified amount of force on a dynamometer hand-grip and so on. Similar within-trial changes in these physiological indices were obtained by Harter, Eason and White (1964) in an experiment which investigated how variations in flicker rate affected rotary pursuit and level of arousal. Although tracking performance varied significantly with flicker rate and illumination level, "the physiological indicants remained essentially constant when flicker rate was varied". This result was interpreted as indicating no change in activation level. However, the subjective experiences of some of the subjects (again only a small sample of sixteen was used) are interesting, two subjects reporting 'sleepiness' at four and/or six cycles, five reporting 'exciting' or 'activating' effects during rates of twelve cycles or higher. Perhaps a clue to the finding of "no change in activation level" is to be found in the fact that all the subjects were experimental psychologists or graduate students, all were familiar with the laboratory and all had previous experience of rotary tracking. This might have been an ideal situation in which to compare physiological indices and tracking performance between subjects but once again average scores across subjects have been taken and this is the data which has been examined.

Stennet (1957) recorded EMG's from four different muscle groups as well as palmar conductance during an auditory tracking task. This was a within-subject study and Stennet reports results which confirm an inverted U hypothesis between performance and level of arousal as measured by both palmar conductance level and EMG response. Various incentive conditions, ranging from one in which the subject was under the impression that his score was not being recorded to one in which his score determined whether or not he avoided a strong electric shock and earned bonus money, were used in an attempt to vary arousal level.

Eason (1963) recorded EMG's from the neck, shoulder and arm during a series of trials over eight successive days on a rotary pursuit task. 'Neuro-muscular control' "measured in terms of the average extent to which the tracking stylus deviated from the target centre within a given work period" increased with each day of practice while the average daily tension level for each muscle remained essentially constant for each target size. Eason interprets this finding as "evidence that the amount of effort exerted during rotary tracking is independent of tracking skill". Performance efficiency was defined here as the ratio of performance quality (degree of neuromuscular control) to tension level. Neck muscle tension alone was found to be as good an indicator of effort as all muscles combined and although "between-subject comparisons revealed no systematic relationship between neuro-muscular control and tension level, . . . those subjects manifesting the least degree of control tended to be the least efficient".

Eason and Branks (1963) attempted a direct test of Duffy's assertion that variations in behaviour have a two dimensional aspect (direction and intensity), and Meyer's efferent neural interaction hypothesis, by having subjects perform a rotary tracking task while simultaneously performing a nonsense-syllable memorisation task under different incentive conditions. Performance and EMG tension levels with the exception of the forehead (frontalis) muscle were significantly affected by different incentive conditions. The results also showed that when a subject is trying hard on the verbal task he is highly inefficient on the motor task and vice versa. Neck muscle tension was again shown to be as sensitive a measure as recordings from other muscles and was more sensitive to incentive variations. Frontalis muscle was least sensitive to incentive variations.

The experimental situation here is rather complex. Eason and Branks found that whether an increase in tension level correlates positively or negatively with performance on the two sub-tasks in this complex task situation depends upon the incentive associated with each. This makes it "apparent that one cannot predict from activation level measures alone, such as the EMG, what is happening to performance".

Sainsbury (1964) reports a highly significant difference in muscle tension recorded from frontalis between twenty-six patients diagnosed as having anxiety states and from thirty control subjects. Autistic gesturing (fidgeting) seems to be associated with anxiety. In fact Sainsbury found a correlation of .47

($p = .02$) between scores on the Taylor Manifest Anxiety Scale and 'fidgeting' score taken from EMG recorded from the arm and forehead.

Berry and Davis (1958) recorded muscle action potentials from three surface locations (jaw, arm and forehead) while subjects performed a serial learning task. No significant relationship between arm potentials and learning scores was found but a significant non-linear relationship between learning scores and the sum of jaw and forehead potentials was reported, the best and the poorest learners having higher potentials than the mediocre ones. The interpretation of these results which these workers favour emphasises MAP changes following verbal responses. "Decrease of activity after a correct response with little or no decrease after an error is favourable to learning, but very poor learners have a similar algebraic difference in the effects of confirmation and correction". For the good learners these effects are in accord with expectations based upon reinforcement theories of learning and on the effects of 'tension reduction'. For the poor learners the muscular activity "may be of another character, such as tendencies to escape, to combat E, to make subvocal ejaculations of surprise or dismay, or other indiscernible activity".

Fjeld (1965) used muscle action potentials as response indicators without 'awareness', finding "a significant improvement in the accuracy of detection of visual stimuli at or below subjects' thresholds when detection was measured overtly by gross muscle movement (subject pressing a key), and covertly by muscle

action potential responses. Fjeld mentions the advantages of using MAP when the response indicator is muscle movement since the measure "provides data within the same response system when an overt response is not given". GSR - verbal report indices which are often used in this type of experiment are not responses which are regarded as measuring the same response system.

Eason, Beardshall and Jaffee (1965) examined skin conductance, heart rate and neck tension in a vigilance situation. Results from a very small sample of six students supported the hypothesis that changes in vigilance are in part determined by changes in activation level. This conclusion held both for decrements frequently observed during the course of a vigil and also variations in the subject's performance from vigil to vigil.

Aarons (1968) examined EMG and EEG together with a number of parameters of a free word association task for diurnal variation. A small sample of subjects (eleven) was used but a number of extremely interesting results was obtained. Free word association reaction time and the mean EMG from all loci (frontalis, submental, right extensor digitorum longus and sternomastoid muscles) correlated .65 ($p < .05$). An average rank of independent rankings of kinesthetic orientation (Mackler and Shoutz, 1964), change seeking (Garlington and Shimota, 1964), and anxiety scores (IPAT anxiety scale, Scheir and Cattell, 1960) correlated -.76 ($p < .02$) with mean EMG taken from all loci during sleep.

Diurnal cycles in reaction time, various measures of

word association performance, body temperature and resting EMG activity were examined. 'Active' subjects (high scorers on the three tests mentioned above) exhibited more EMG activity when awake (excluding submental EMG) than 'passive' subjects (low scorers on the tests). During sleep the reverse held i.e., 'actives' showed less EMG activity than 'passives'. An important general finding of this study is that qualitative parameters of word association (vocabulary skill, tendency to dimension-type responses, e.g., milk - cream, oil - gas etc., etc.) "co-vary significantly with physiological arousal as indexed in diurnal levels of EMG intensity. The evidence . . . strongly implies that arousal includes both energising and directive effects in ideation or mental activity".

Pishkin and Shirley (1968) examined concept identification performance as a function of physiological arousal. Subjects werepsychiatric patients and the number in each experimental group was small. Results showed a positive correlation between CI (concept identification) errors and muscle action potential (MAP) ($r = .62$ $p < .01$) and a significant ($r = -.39$ $p < .05$) negative correlation between number of spontaneous GSR's and MAP. Examination of GSR's and MAP's in problems of varying complexity together with the findings reported above, supported the interpretation "that MAP reflects internal disturbance associated with inability to process information while spontaneous GSR's reflect successful information intake".

What overall conclusion can be reached from studies

which have used muscle tension as a variable? Firstly, a response of any sort implies some sort of muscle activity; secondly, that muscle tension may produce and/or may reflect heightened cortical activity but that this also, depending upon the situation, may be either beneficial or detrimental to performance in a wide variety of situations. EMG, as Davis (1956) has pointed out, as a 'real' intervening variable "may be useful in understanding responses because, in the first place it provides quantification of the overt responses, and in the second place, it is a description of aspects of the response process which are otherwise hidden from view".

3. Eyeblink Rate

Meyer (1953) puts forward a theory that simultaneous responses are interrelated as a function of the degree of overlap between the activated motor pathways. Developing this idea he suggests that almost every response the human being can make should alter his tendency to blink because "the motor mechanism for the eyelid is strategically placed between the pathways for the face and hand" (Meyer et al. 1953), and that the spatial distribution of activity in adjacent pathways can be determined indirectly by measurement of muscular tension patterns. Luckiesh (1946) and Bitterman (1945) are cited as producing evidence for and against the notion that alterations in the pattern of activity in a response can be detected by examination of blink rate. The research by Meyer et al. (1953) shows significant changes in

blink rate when monetary incentives were introduced in a pursuit task and a positive correlation between performance and blink rate of subjects who were given incentives late in the practice series. Blink rate was not recorded during the task but in a 30 sec. rest period which followed it. No relationship was found between scores on an inventory made up of "items related to tension which were taken from the Taylor inventory and a number of others related to motivation", though a correlation was found between individual blink rates and scores on a "maladjustment index based upon the Rotter sentence completion test". Doehring (1957) also found no correlation between T.A.S. scores and blink rate (and finds this surprising in view of the fact that the Taylor scale was used in the Meyer et al. (1953) study!!). However, accepting rate of eyeblink as a definition of generalised muscular tension, Doehring found that this showed a greater increase in response to stressful verbal stimuli (afraid, failure, solo, crash - the subjects were naval aviation cadets) than to neutral or non-stressful words (pepper, window, paper, flower) and that anxiety level defined by responses on the Saslow Screening Inventory is positively related to the amount of tension produced by verbal stress stimuli. Longo and Doll (1962), following these studies, found a positive relationship between a blink-rate measure and ratings of stress susceptibility.

Eason, Beardshall and Jaffee (1965) used a composite recording which they termed eye-region response. The composite electrical response of activity (detected with electrodes placed

above and below the eye) of the eyelid and of vertical eye movements was integrated using a pulse-frequency electronic integrator. It was found that during a vigil ERR tended to behave as did a neck tension measure though unlike this measure the rise during the vigil was not statistically significant. They conclude that at least ERR seems to be a poor substitute for neck tension measure.

Although the relationship between generalised muscular tension as measured by, for example, EMG, from a sample of muscle groups and eyeblink-rate does not seem to have been established, it does seem that some effort should be made to see if some such relationship exists, for eyeblink is a very easily observed and recorded phenomenon and its use as an index of muscle tension and hence perhaps of arousal could be widespread.

A simple and effective system adapted from a device described by Griffith and Sparks (1961) can be used for recording eyeblinks. (See Chapter IV, page 113). Ambient light is all that is necessary, the subject soon becomes used to wearing the device, forward vision is not obscured and a good permanent record can be obtained. (See Appendix 5). Doehring used a strain gauge positioned about 3/8 inch from the corner of the eye as a recording instrument. Meyer et al. and Longo and Doll merely counted the directly observed blinks.

4. Figure Reversal

Köhler and Wallach (1944) offered the hypothesis that

it is satiation which induces reversal in a reversible figure ground organisation. Hochberg (1950) tested the hypothesis by satiating one alternative of a reversible figure ground and showing that in subsequent fixation of the reversible pattern, the opposite alternative tended to predominate over the satiated alternative, and Carlson (1953) reports results which support this finding.

Hebb (1955) has discussed the arousal function of sensory events and explained (1958), the phenomenon of figure reversals in terms of the satiation of the cell assembly mediating each perspective. When this process reaches a particular critical level then a reversal occurs. Orbach, Ehrlich and Heath (1963) propose that it is satiation of orientation - a hypothesised central fatigue process - which is responsible for reversal, and Orbach and Zucker (1965) presenting a Necker cube tachistoscopically and interrupting the process of satiation by interpolating a non-reversing cube of the preferred perspective showed that the preferred orientation could be altered. Their results support the view that satiation of <u>orientation</u> is responsible for reversal.

Cesarec and Nilsson (1963a) suggest that figure-ground fluctuation frequency might be related to alertness attention level. The reversible figure used was a double Maltese cross divided into sections by two so-called Archimedean spirals of equal breadth, one completely white, one yellow in the sections of one cross and black in the other. When rotated either a yellow cross and black spiral or a black cross and no black spiral is

seen and these two figures alternate. The subjects were presumed to be in a high state of alertness because of instructions to observe the figure and "a state of more or less tense expectation was induced by the information that an intra-muscular injection would be given". A significant relation "between higher and more varying systolic blood pressure on the one hand and figure ground fluctuations of higher frequency on the other was found".

In a further study, Cesarec and Nilsson (1963b) made intra-individual comparisons of a number of physiological indices of what they describe as 'alertness-attention' level - skin conductance, finger pulse amplitude, respiration rate and figure-ground reversals. The results showed among other things, that the more marked a measure of the 'habituation tendency' of skin resistance (defining the step-by-step increase of skin resistance during observation periods - in fact, stimulation periods), the less the fluctuations tend to increase in frequency. This agrees with the finding of a relationship between low finger pulse amplitude and high fluctuation frequency. Comparison of different observation periods of fluctuation frequency with the respiratory frequency curve showed no relationship. In the main, these results support the hypothesis that a relationship exists between alertness-attention level and fluctuation frequency.

Corah (1960) investigated the relationship of palmar skin conductance as an index of arousal to a kinesthetic after-effect task and figure reversal (as measures of 'satiability') and "a third perceptual task, disjunctive reaction time". There

was no relationship between any of the 'performance' measures. A curvilinear relationship was established between mean reaction time and log conductance (Eta = .52, F = 2.96, $p < .05$). Dividing the subjects into three groups on the basis of their palmar conductance and comparing the 'middle half' with the two 'outer quarters' showed a non-linear relationship. Subjects with middle range conductance scores had significantly more reversals and a larger mean percentage decrement of kinesthetic after-effect than subjects in the low and high conductance groups.

Kidd and Cherymisin (1965) report among other findings that mean reversal time (i.e., time to first reversal) is related to anxiety, the longer the average reversal time the higher the score on the Taylor MAS.

Sherwood (1965) also proposes, on the basis of Hebb's explanations, that figure reversals per unit time might be an index of arousal and examined this index in relation to performance on a paired-associate learning task. Rates of figure reversal (Necker cube) and retention scores were correlated ($r = .39$, $p < .01$) and a t test between mean rates of figure reversals for 'high arousal' subjects (median reversals = 28) and 'low arousal' subjects (median reversals = 10) gave a value of 2.88 ($p < .01$). "A tri-serial correlation between subjects' subjective reports of feelings of arousal and rates of figure reversals gave a significant correlation ($r = .87$, $p < .01$)". There was no evidence of a curvilinear relationship between performance and level of arousal.

Oswald (1962) reviews some of the work which helps to explain fluctuations in 'cerebral vigilance'. "Afferent impulses from the baro-receptors of the carotid sinus and aortic arch have a damping effect on the reticular formation and bring about EEG changes characteristic of sleep". Raisihg the pressure within the carotid sinus of a dog brings about sleep. Rhythmic fluctuations of cortical vigilance appear to relate to rhythmic fluctuations in blood pressure (Mayer waves). They occur in man even when at rest and have a periodicity of ten seconds or so. Oswald (1959), describes a man in whom after-images to a 'conjured-up voluntary vivid image' fluctuated in size at the rate of his arterial pulse. Not only apparently can cerebral vigilance fluctuate at rates comparable to the pulse but also with the respiratory cycle. The subject in Oswald's study "also experienced respiratory fluctuations in the size of his after-images reporting shrinkage at the end of inspiration".

Eysenck et al. (1957) have established a link between reversibility rate and introversion-extraversion but subsume the physiological concomitants (satiation and reactive inhibition) under the rubric of 'reactive cortical inhibition'.

Meredith (1967) reporting that, "In Cattell's multivariate theory of personality, frequency of fluctuation (labeled as Master Index 8) has been found to be a stable marker for 'cortertia' factor, designated as Universal Index (U.I.) 22 . . . To a lesser degree, reversal rate enters into U.I. 19 (Promethean Will) and U.I. 23 (Mobilisation), factors of personality involving

"tense reaction-impetus" or over-readiness to respond", has examined a number of rating dimensions which might describe the reversibility phenomena of the Necker cube (static-dynamic integrated-fragmented, near-remote etc.). 'Rigidity' as measured by the 'California Personality Inventory' seemed to be unrelated to reversibility but 'Anxiety' as measured by 'IPAT Anxiety Scale Questionnaire' seemed to influence ratings in the 'activity' domain. Meredith concludes, "the perception of vitality and élan in . . . figure reversal appeared linked to tension within the system - suggestive of a 'spilling-over' of system energy into the perceptual-motoric regions", which conclusion can be accommodated within a field-theory framework (Deutsch, 1954).

Measures of figure reversal are usually taken by asking the subject to tap the table or to raise a finger whenever a reversal occurs. A permanent record may be obtained by requiring him to press a key which is connected to a marker pen. This is obviously essential when accurate measurements of, for example, time to first reversal are required.

5. Heart Rate

It appears that the most important automatic regulator mechanisms are located in the medullary reticular formation, the chief among them being the respiratory, vasomotor and cardio-inhibitor (vagus) centres. In the case of the heart it is evident that higher nervous centres are not ultimately responsible for its beat since the excised mammalian heart will continue to beat

for a considerable time provided that a warm oxygenated fluid of suitable composition is supplied to the heart muscle via the coronary vessels. The heart does contain nerve ganglia mainly derived from the vagus nerve but even if these are excised the beat continues. Heart muscle itself possesses the property of contracting rhythmically.

It has been shown by recording the spread of electrical activity over the heart muscle that the change associated with contraction begins in the sino-auricular node (the pacemaker) spreads in all directions over the auricles, arrives at the auriculo-ventricular node and is relayed through the ventricular muscles by the fast-conducting Purkinje tissue.

Both the sympathetic and parasympathetic divisions of the autonomic nervous system supply the heart. The action of impulses travelling in the vagus (parasympathetic) nerve is to slow the heart by action on the pacemaker. The sympathetic fibres arise in the middle and inferior cervical ganglia and terminate around the pacemaker and the auriculo-ventricular node. Activity in the cardio-acceleratory centre (also located in the medulla) acts via the cardiac nerves to quicken the heart, again by action on the pacemaker and also by facilitation of conduction from auricle to ventricle. Normally impulses pass to the heart along each set of nerves because section of the vagus quickens the heart and section of the sympathetic slows it.

"The number of impulses passing along the vagus and sympathetic nerves to the heart and thus the heart rate, are

chiefly determined reflexly through the depressor and carotid sinus reflexes. By means of these reflexes a rise of pressure in the aorta and carotid arteries slows the heart and a fall of pressure quickens it". (Winton and Bayliss, 1955). Higher cortical activity also affects the heart rate via the cardiac nerves as is seen by the increase in rate during, for example, fright. Heart rate also increases when body temperature rises and this is thought to be by direct action on the pacemaker.

The action of the heart is best recorded as the electrocardiogram (EKG). The electric activity accompanying the cardiac cycle is conducted to the body surface by the body fluids - mainly the blood in the main vessels. Two electrodes placed some distance apart on the body surface will pick up signals from the heart. However three standard limb leads are usually employed in psychological work, though additional chest leads are used in clinical work. The leads are I. Right arm. Left arm. II. Right arm. Left leg. III. Left arm. Left leg. After suitable amplification the signals may be recorded as the EKG on a pen recorder or oscilloscope film. Each of the three leads gives a slightly different record but the pattern formed is characterised as the PQRST wave. The P-wave is associated with contraction of the auricles, the QRS complex is associated with ventricular excitation and the T-wave with the repolarisation of the ventricles.

A number of systems based upon the production of a uniform square wave 'shaped' from the peak amplitude of the R-wave are available which enable heart rate to be recorded

directly. Using such a system means, of course, that other measures which can be derived from the EKG are lost.

A number of studies have investigated relationships between performance and cardiac rate, the latter being considered as a measure of autonomic arousal.

Blatt (1961) recorded heart rate from subjects engaged in complex problem solving. Elevations in cardiac rate were noted in efficient subjects particularly, "at crucial moments in the thought process", even though they were unable to identify these moments in retrospect. Blatt interprets his findings in terms of the idea that "autonomic arousal during efficient functioning reflects the general tendency toward higher levels of cortical excitation". An interesting point in this study is that although subjects had no idea of their relative degree of efficiency - there was no way by which they could judge their performance - both efficient and inefficient subjects expressed feelings which seem to indicate that they were well motivated, and inefficient subjects "tended to report a higher degree of arousal or tension". Clearly, this illustrates the dangers of 'inducing arousal' in experimental situations and then checking on the degree of 'arousal' by questioning the subject. Blatt notes, "the difference in arousal patterns of efficient and inefficient subjects does not seem to be simply an issue of the degree of motivation, but rather more one of the type of motivation".

A conceptual scheme "which considers cardiovascular activity as instrumental in enhancing, or rejecting, environmental

inputs", received support from a study by Obrist (1963). Heart rate, systolic blood pressure, peripheral blood flow, skin resistance and respiration were measured prior to and during six different stimulus conditions (two noxious stimuli, a conceptual task and three conditions 'requiring close attention to environmental inputs'). Noxious stimuli and the conceptual task produced heart rate acceleration, increased blood pressure, vasoconstriction and decreased skin resistance. The 'environmental input stimuli' produced cardiac deceleration, decrease in skin resistance and unchanged blood pressure and flow. There appeared to be little consistency in relationships between the magnitude of respiratory rate and heart rate changes. The magnitude of heart rate change was found to be unrelated to the magnitude of skin resistance change except for one of the 'environmental input' situations when a low order positive correlation was observed.

Lazarus, Spearman and Mordkoff (1963) established substantial relationships between heart rate and skin conductance when intra-individual correlation techniques were applied particularly in a stressor condition (viewing a stressful film). They conclude, "different autonomic indicators of stress do indeed rise and fall together, as degree of stress waxes and wanes. This cannot be shown by inter-individual statistics . . . " Fortunately, the authors do report the inter-individual correlations. For the control film ('Corn farming in Iowa') the figure given is +0.301, and for the stressor film, +0.162, commenting that "this correlation of heart rate and skin conductance under the stressor

condition is, as typical of findings based on the traditional inter-individual analysis, very low". However, it is worth noting that a coefficient of 0.301 (assuming that the "traditional method" employed was Pearson r) is, with an n of 50, significant beyond the .05 level of confidence, and it is also interesting to note that this was obtained in the control condition.

Spontaneous autonomic activity has been investigated by Johnson (1963). He found that though spontaneous GSR was moderately stable over a 48-hour period (rho = 0.69) spontaneous heart rate was less reliable (rho = 0.36). Surprisingly, spontaneous HR showed ho change during tone and flicker stimulation (pre-stimulus measure here was the average of three fastest beats in a ten second interval and the 'response' measure was the average of the three fastest beats within five seconds of the onset of the stimulus). Johnson feels that, "it is probable that changes in heart rate are a complex phenomenon depending upon the integration and interaction of several physiological systems". This work is one of a number of studies which appeared after the work of Lacey and Lacey (1958) which showed that spontaneous physiological activity was related to performance on a task which measured 'motor impulsivity' (the task was fairly complicated but was essentially a reaction time situation which included both 'respond' and 'do not respond' stimuli). Doctor, Kaswan and Nakamura (1964), investigating both spontaneous heart rate changes and spontaneous GSR's and comparing them to performance on an almost identical task to that used by the Laceys, failed to

confirm the relationship. This was true both for the complex task and for simple reaction time. Doctor et al. conclude that if spontaneous activity is related to impulsivity then the conditions under which this is demonstrated must be quite specific.

In a study which examined a number of physiological measures (density of finger sweat prints, palmar conductance, heart rate, respiration rate and electromyogram levels) Malmo (1965) found a number of low but significant intercorrelations. Performance on a tracking task was measured under high and low incentive conditions. Palmar conductance correlated significantly with respiration and with heart rate. The latter correlated with respiration and with the electromyogram measures. Palmar conductance, heart rate and the electromyogram measures all correlated with performance. In fact heart rate correlated with every other variable used except for finger sweat print density. Various differences in the degree of correlation were noted in the different incentive conditions and Malmo notes that "situation specificity is undoubtedly extremely important in determining which physiological measure will turn out to be the best discriminator in a given investigation". It seems as though in his later work Malmo is turning away from his insistence upon intra-individual studies and is providing fairly impressive evidence for some degree of correlation between physiological measures. Clearly this study is completely at variance with a number of other studies cited by Plutchik and Ax (1967) when they state that "pulse rate . . . has been shown to be an ambiguous measure of

arousal and has little correlation with other physiological measures".

Yet another contribution by Lacey to the field of research on autonomic responses is his work, first reported in 1959, on "directional fractionation" and the "intake-rejection" hypothesis. Directional fractionation refers to the observation that heart rate shows a decrease in some situations where other activation indices such as skin conductance show an increase. Lacey found that the phenomenon was observed in conditions which involved environmental 'intake' e.g., listening to an unpleasant story or to white noise. It was not seen in situations which gave attention primarily to thought processes rather than the external situation e.g., sentence completion and mental arithmetic and thus involved 'rejection' of the environment. These observations were not confirmed by Campos and Johnson (1966), who recorded heart rate and skin conductance under different levels of instruction to verbalise and with visual stimuli of increasing complexity. On the other hand the experiment of Obrist (1963) which has already been described and several further studies by Lacey and co-workers support Lacey's generalisation. Edwards and Alsip (1969) presented a tone at five intensities which spanned the subject's intensity threshold during periods when transient heart rate was low and high. There was no difference in the number of correct detections under high and low heart rate and the writers conclude that heart rate "is not a <u>sufficient</u> correlate of perceptual sensitivity", though they do note that

although a clear difference was obtained between the high and low rates for each subject (a difference which was often greater than those in the 'perception-cognition' experiments in this area) using "natural" rather than experimentally-induced heart rate levels might be inappropriate. "Perhaps a much lower HR, below the S's 'natural' range, is a necessary condition". Johnson and May (1969) suggest that the cardiac deceleration which they observed during a reaction time foreperiod and during a time estimation period might be coupled with somatic responses. They note that "the critical aspects may be the response and motor components which are common to both tasks" and may not be direction of attention at all.

There seems to be little doubt that changes in heart rate are linked to a variety of performance conditions. The nature of the link remains uncertain and it seems likely that it is affected in different ways in different situations. Though the value of heart rate as a reliable index of performance is not yet demonstrated, the wealth of studies where it has been employed attests the interest which it has generated and the challenge it has presented.

6. Respiration

"Respiratory movements are usually carried out automatically and unconsciously, but involve highly complex nervous activity in both the autonomic and somatic spheres. The process of respiration emphasises both the high degree of integration

among all levels of the central nervous system and the complexity of one of the first instinctual acts of man". (Goldensohn, 1955).

Pitts, Magoun and Ranson (1939) and Pitts (1941) investigated the differentiation of respiratory centres in the medullary reticular formation showing that electrical stimulation of an area in the ventral reticular formation produced sustained inspiration and stimulation of the dorsal area caused strong expiration. Further, simultaneous stimulation of these two areas produced inspiration, suggesting that the ventral inspiratory area is the dominant one of the two. A number of other factors also play a part in the rhythmicity of breathing most notably the stretching of the lungs during inspiration which results in impulses being sent along the vagus nerve which stimulate the expiratory centre which in turn inhibits the inspiratory centre. In addition, there is a 'pneumotaxic centre', in the pons which although it plays a secondary role to the vagus nerve in determining respiratory rhythm is important in that it receives impulses from hypothalamic thermoregulatory areas and thus affects the increase in respiration when body temperature rises. The respiratory centre is also affected directly by the carbon dioxide pressure and hydrogen ion concentration of the blood and indirectly by chemoreceptors and pressoreceptors in the carotid artery and aortic arch which are sensitive respectively to oxygen tension and blood pressure changes.

Clausen (1951) reviews a number of earlier studies, mainly clinical, in which attempts have been made to relate

respiratory patterns and changes in respiratory patterns with a variety of emotional states, mental disorders, personality types and modifications of states of consciousness. The studies reveal little or no uniformity although the broad observation of, for example, the rapid, shallow breathing in pleasurable states and the irregularity and sighing in anxiety states is well-established. The lack of uniformity in these studies can probably be accounted for in terms of the influence of conscious and voluntary processes on respiration. Respiration is probably more susceptible to such influences than any other normally 'automatic' process. Goldensohn (1955) notes, "It is easily observed that simply being attentive to one's own respiratory patterns results in their alteration. The ability to voluntarily stop breathing for a limited time and the fact that voluntary effort can accomplish greater ventilation than the most strenuous muscular exercise suggests that areas rostral to the hypothalamus have the ability to induce all the types of respiratory changes encountered from the more caudal areas of the brain".

As already stated, the studies involving respiratory measurement have yielded somewhat conflicting results. This combined with the fact that the number of studies is small, probably accounts for the lack of interest in or enthusiasm for respiration as an index. Nevertheless reports continue to appear.

Gaskill and Cox (1937) examined a number of respiration measures (rate, largest amplitude, 'number of atypical breaths', Inspiration - Expiration ratio and variability in depth of

breathing) in a variety of situations (rest, surprise, fear-producing). They found that there was little overlapping of the patterns of respiration between the measures and between the situations, concluding that "the pattern in respiration is exceedingly complex perhaps even a complex of many variables".

Brower (1946) examined the effects of sensory motor conflict (induced by requiring subjects to carry out a mirror-tracing task) on respiration and blood pressure. The 'Woodworth I-fraction' (Inspiration - Respiration ratio) bore an inverse relationship to the magnitude of time and error deviations and multiple correlation of the I-fraction, at rest and before conflict was induced, with blood-pressure deviations yielded a figure of 0.86. Brower concludes that the resting I-fraction may be a measure of "frustrationality and emotionality". Although there was no significant relationship between pre-conflict and conflict scores for blood pressure, "significant positive relations exist between basal respiratory measures and their deviations under conflict".

The influence of respiratory cycle on motor activity was suggested by Johnson and Luckhardt (1928) who found that the knee jerk reflex was diminished when pressure in the lungs was raised. They postulated a reflex inhibition due to mechanical stimulation of the vagus. Buchsbaum and Callaway (1965) cite a number of studies which suggest that "stimulation of the vagus during inspiration provokes a reflex motor inhibition." They found when reaction times were measured during spontaneous

breathing and when a foreperiod warning light warned S to hold his breath in either inspiration or expiration, that faster reaction times occurred during expiration. These writers quote the work of both Russian and German workers who ,working independently, produced opposite results i.e., short reaction times on inspiration, the Russian researchers suggesting that discharge of the inspiratory centre "sends a wave of excitation coursing through the central nervous system".

Very recently, McCollum, Burch and Roessler (1969) examined respiratory amplitude and rate after sound and light stimulation in a group of student subjects who had completed the Minnesota Multi-phasic Personality Inventory. The group was split into high and low ego-strength sub-groups balanced for alertness-drowsiness by EEG criteria. High ego-strength subjects showed significantly greater respiratory excursion and a slower rate than low ego-strength subjects. The writers point out that differences may be due to anxiety. Ego-strength and anxiety are usually inversely related and the two sub-groups did differ significantly on scores on the Taylor Manifest Anxiety Scale.

Recording of the respiratory cycle presents few problems. The movements of the chest wall are caused by the active inspiratory phase of respiration when the diaphragm descends and the chest is pulled outwards and upwards by the intercostal muscles, followed by the passive expiratory phase when the intercostal muscles and diaphragm relax. These movements of the chest wall can be recorded by placing an air-filled tube around the chest

and recording changes in pressure via a tambour diaphragm or strain gauge pressure transducer. Alternatively a tube filled with mercury, colloidal graphite, or an electrolyte can be employed. The electrical resistance recorded between two separated terminals within the conducting medium will increase as the tube is stretched and decrease when it recoils. Using a Wheatstone bridge circuit this varying resistance can be converted to a varying voltage which, after suitable amplification, can be recorded.

The disadvantage of these 'chest-tube' methods is that they will record all gross movements of the subject's chest, movements which are not necessarily associated with respiration. They are really therefore only useful where the subject remains comparatively inactive.

An alternative system avoids this difficulty. Thermistors or thermocouples which will convert changes in temperature to electrical changes may be attached to the subject's nostril or mouth. Respiratory activity of course produces temperature changes in the nose and mouth and these changes may be recorded. In the main this system is not very satisfactory, because of the difficulty of satisfactorily positioning and attaching the device to the subject so as not, at worst, to cause discomfort and at best, so that the subject is not aware of it.

The evidence for the usefulness of respiratory measures as indices is admittedly not plentiful or persuasive. Nevertheless there are significant indications that in some circumstances

they might yield dividends and their comparative ease of recording and measurement make it worthwhile to include them, if only to speed their final adoption or rejection.

7. E and N Scales

Eysenck (1947) has identified the primary personality dimensions of neuroticism-stability and extraversion-intraversion which are the basis of the N and E scale scores used in the present study. Since this study Eysenck himself and a number of others have explored the relationship of these dimensions with a variety of behavioural variables, at the same time producing many ideas about the nature of the dimensions themselves and the causal factors which will account for an individual's position on these dimensions. A very great deal of literature has resulted from these efforts much of which is reviewed by Eysenck himself (1967). Once again the main points will be dealt with here and a selection of the supporting literature cited.

The dimension of neuroticism-stability or emotionality is related to the lability of the autonomic nervous system, and introversion-extraversion to the concepts of inhibition and excitation put forward by Pavlov and developed by Hull in his theory of learning. (Eysenck, 1957). In fact Eysenck develops his theory in learning theory terms. An individual who is high on the factor of neuroticism would be characterised by a high level of drive in avoidance situations. A number of studies have attempted to explore the relationship between autonomic reactivity

and neuroticism. Hoch, Kubis and Rouke (1944) report greater activity of the GSR in neurotics than in normals though Altschule (1953) reviewing the literature casts doubt on the generality of this finding. Eysenck (1956) found significant differences in the "rate of calming down" of neurotics compared with psychotics and normals though she failed to find any differences in responsiveness. Differences in reactivity following a task seem to have often been noted. For example, Eysenck (1967) reports an experiment performed by Wing in which neurotics and normals were compared on a stress task which found that the skin conductance of normals quickly returned to a resting level whereas neurotics showed an increase in conductance. A number of experiments have been reported in which attempts have been made to induce drive e.g., Willet (1964) who found that in all cases at all levels of difficulty the high drive groups were superior on a paired associate learning task.

The conclusions reached by Eysenck (1967) in summarising this work are broadly, that autonomic lability and emotionality are related, that emotion acts as a drive and "may lead to facilitation of performance or deterioration of performance depending on complex interactions between amount of drive present, task difficulty, stress experience", and other variables.

Diamond, Balvin and Diamond (1963) have examined the concept of inhibition. Pavlov was one of the first to use the term and to give it a physiological explanation. Eysenck (1967) has attempted to give the concept a "physiological reference" but

his general description will suffice for the moment, "Let us merely regard excitation as referring to cortical processes of an unknown character which facilitate learning, conditioning, memory, perception, discrimination, thinking, and mental processes generally, whereas inhibition has the opposite effect of reducing the efficiency of the cortex". Hull's concept of reactive inhibition which he stated in 1943, is, "Whenever any reaction is evoked in an organism there is left a condition or state which acts as a primary, negative motivation in that it has an innate capacity to produce a cessation of the activity which produced the state". He identified this state with fatigue. It now seems to be more appropriate to look upon inhibition as a central phenomenon rather than the result of physical work. In 1957 Eysenck postulated the relationship between personality and inhibition as follows: "Human beings differ with respect to the speed with which excitation and inhibition are produced, the strength of the excitation and inhibition produced and the speed with which inhibition is dissipated. These differences are properties of the physical structures involved in making stimulus-response connections". Secondly, "Individuals in whom excitatory potential is generated slowly and in whom excitatory potentials so generated are relatively weak, are thereby disposed to develop extraverted patterns of behaviour . . ." Introverted patterns of behaviour tend to develop in individuals who generate strong excitatory potentials quickly. Similarly strong reactive inhibitions which develop quickly are found in individuals predisposed to extraversion, the

converse being true in the case of introverts.

Gray (1965), in examining Pavlov's contribution to this area, describes the later work of Teplov, who developed the idea of a 'strength-weakness' dimension of the central nervous system which Eysenck feels bears some similarity to the notion of an excitation-inhibition balance which he has developed.

Claridge (1961) reports on an experiment which compared dysthymics (neurotic introverts) and hysterics (neurotic extraverts) on a five-choice serial reaction time task. The prediction that dysthymics would perform at a significantly faster rate than hysterics was confirmed. Claridge's hypothesis is that the behaviour of hysterics and dysthymics reflects the extremes of an interaction between arousal and inhibition. An individual's position on the introversion - extraversion dimension in part reflects his level of inhibition. Claridge suggests that "An additional factor is that the presence of low and high arousal levels, respectively, is likely to result in a shift towards even greater inhibition in hysterics and correspondingly less inhibition in dysthymics".

Furneaux (1962) hypothesised that the N scale might be a measure of generalised drive or activation level and reports that neurotic introverts showed superior university performance. Corteen (1965) found no relation between the N scale and basal skin conductance but a highly significant correlation (-0.43, $N = 76$, $p < .001$) between the N scale and the average mark for two university class examinations. However, Corteen does not

support the notion of the N scale as a measure of potential drive level but rather as a scale of "degree of inadequacy" - the degree to which an individual can or cannot cope with the current situation. The N scale does of course differentiate between neurotics and non-neurotics as clinically defined (Eysenck, 1959) but Corteen points out that there is a marked overlap "many non-neurotics falling more than one standard deviation above the neurotic mean, and it could be that the observed difference between the mean scores simply reflects a tendency for neurotics to be less adequate in certain situations".

A further experiment by Corteen (1965) investigated the performance of high and low N scale scorers "in a task where their adequacy to deal with situations of different degrees of complexity could be compared". (The task was in fact, rote learning of nonsense syllables at different rates of presentation). The difference between the high N and low N scorers was significant at the .01 level for the fastest rates of presentation. A later experiment reported, though not performed, by Corteen found a significant correlation between time to learn a list and N scale score, at fast exposure rates. Corteen concludes "It does seem likely, that adequacy is a valid personality dimension . . . which is reflected in the way individuals react to situations, both intellectual and social, which require complex patterns of overt response".

As already mentioned, Eysenck, following Pavlov, has argued that extraverts are marked by an excess of cortical

'inhibition'. Extraverts therefore condition poorly and introverts condition particularly well. Most of the work investigating extraversion and performance has been directed to examining this assertion, one of the earliest and most clear cut results being obtained by Franks (1956) who established the difference between extraverts and introverts in an eyeblink conditioning experiment. Al-Issa (1964) however has produced results which suggest that the relationship between eyeblink conditioning and personality measures (extraversion, neuroticism and anxiety) is complex and inconsistent since manipulation of the subjects' attitudes by varying instructions, scoring techniques and experimental procedures, can affect the results profoundly.

Eysenck (1963) has also postulated that extraverts would be relatively insensitive to incoming stimuli. Teplov's work reported by Gray (1965) is again relevant here, his 'strong' nervous system being less sensitive to stimuli. Smith (1968) attempted to test the hypothesis that extraverts have higher auditory thresholds than introverts and produced results which give it strong support. In his conclusion, Smith makes the interesting point that "Since 'inhibition', in Eysenckian terms, is unlikely to play a part in auditory threshold determination, the results of this experiment may be thought to give some support to the idea that introverts are marked by higher levels of excitation or arousal than are extraverts".

In summary, although the use of the E and N scales as indices of arousal is relatively rare and when relationships

between these scales and performance measures have been found they have not necessarily been interpreted within an Eysenckian framework, there does seem to be some justification for including them in our investigation. The use of a paper-and-pencil test as an instrument has a (dangerous) attraction to many psychologists and the present writer is no exception to those who dream of the valid, reliable, multi-dimensional, all-embracing, all revealing, personality test and yet in their heart-of-hearts believe it to be nothing more than a dream.

8. Further Indices of Activation

The measures discussed above do not exhaust the possible indices of activation nor can any claim be made for them as being necessarily the 'best' ones to employ. There is however, as has been seen, a fair body of knowledge which indicates that further investigation of them might be worthwhile.

A variety of other physiological functions have, on a number of occasions, been measured and correlated with general arousal level and emotional reactions. In the context of the present study there is little point in doing much more than listing them.

Electroencephalographic (EEG) phenomena are widely employed and although these manifestations can hardly be termed peripheral, they do represent as mentioned in Chapter 1, physiological indices of arousal, and they are affected by activity in the brain stem reticular formation.

Apart from heart rate, other circulatory and vascular factors have been examined. In particular, blood flow and blood volume changes have been measured using a variety of plethysmographic techniques. Blood pressure has also been monitored in a wide variety of situations.

Skin temperature, which is determined by a rather complex interplay of vasomotor activity, blood temperature and general body temperature appears to be associated with differing emotional reactions.

Sweating indices, for example finger sweat print densities, although associated with changes in body temperature may have independent utility. The 'cold sweat' of extreme fear is at any rate well known in the mystery novel.

Measures of metabolic rate, which are dependent upon oxygen consumption and carbon dioxide excretion indices, have been used in studies of emotional state, though the literature does not seem to be extensive and the findings are somewhat equivocal.

Gastric and intestinal motility, although measures of them are not often employed (probably because the recording techniques are rather unpleasant and therefore likely to induce 'emotional' reactions) are nevertheless well known as being associated with a variety of arousing and emotional situations.

Blood sugar levels as well as other biochemical measures such as epinephrine - norepinephrine balance and hippuric acid secretion are among the possible biochemical indices of emotional reactivity and general arousal.

The 'dry mouth' of fear and trepidation has its quantitative counterpart in the physiological laboratory in the measurement of salivary output in different emotional states.

In laboratory animals the erection of body hair - the pilomotor response - is very often used as an observational index of rage and fear but has been little if at all used as a quantitative measure.

Change in pupil size during a variety of stimulus situations (other than changing light stimulation) has recently been examined as a possible index of emotional reaction.

In Chapter I the difficulties in adequately defining 'activation' have been mentioned. The definition of 'emotion' is perhaps even more difficult since it involves both expression in terms of bodily and autonomic responses, and experience in terms of what is felt by the individual. In many discussions the two concepts are intermingled and their study in relation to all the variables which have been mentioned in this Chapter takes place against a background of some confusion which is often a matter of semantics.

III THE MEASUREMENT OF PHYSIOLOGICAL INDICES

The most cursory glance through the literature indicates how little notice has been taken of attempts to rationalise the measurement of autonomic reactions. Many ingenious attempts have been made to overcome the statistical and measurement problems involved in comparing the same autonomic changes on different initial levels between individuals. Wilder formulated his law of initial values as long ago as 1930 but it was not until J.I. Lacey published a monograph in 1956 that interest in this problem was revived. Since that time a number of solutions of the problem of the evaluation of autonomic responses have been suggested. An adequate solution would of course be of immense value in examining any lack of correlation between physiological indices, since the suspicion must be that many of the results obtained in this research field are based upon inappropriate scoring techniques.

1. Electrodermal Measures

Having obtained our recordings of the relevant responses in as effective and efficient and artefact-free method as possible, the problem of measurement and mathematics has to be faced. This very real problem is emphasised by the vast literature on electrodermal phenomena and the many ways in which attempts have been made to quantify it. As Woodworth and Schlosberg (1955) point out in a review of the use of skin conductance "Far too often we

select our units because the dial happens to be engraved with that type of scale (usually ohms)". When it comes to comparing individual galvanic skin responses, how do we compare a change of 500 ohms on a baseline of 20,000 ohms with a change of 500 ohms on a baseline of 40,000 ohms? Lacey (1956) says "In comparing individuals or groups, then, one does not know whether to attribute differences in obtained reactivity to pre-existing differences in the background level of autonomic excitation, or to reactivity per se". With regard to electrodermal phenomena the approach has been to investigate mathematical and statistical transformations of the data which will provide measures of GSR which are independent of basal level of resistance. (Seward and Seward, 1935; Wenger and Irwin, 1936; Darrow, 1937; Haggard, 1945, 1949; Lacey and Siegel, 1949; Paintal, 1951; Elliot and Singer, 1953). Lacey (1956) notes the "bewildering array" of transformations which has resulted: "the logarithm of the change in conductance; the change in the logarithm of conductance; the logarithm of change in resistance; the ratio of the logarithm of the change plus a constant divided by the resting level; the percentage change in resistance; the square root of conductance; the percentage any given ohmic decrease is of the maximum ohmic decrease obtained, and others". The confusion which may result is perhaps illustrated and emphasised by the fact that Woodworth and Schlosberg's (1955) review and worked example do not clearly distinguish between log conductance change and change in log conductance. According to Lacey and Siegel (1949) the former is an

appropriate, the latter an inappropriate measure. Even Lacey himself (1956) describes "log micro-ohms" as a conductance measure though strictly speaking this is a resistance measure. This, however, may be a printer's or proof-reader's error. The general method of approach - that of statistical manipulation - can best be described by examining Lacey and Siegel's (1949) report in more detail. This report is chosen because their preferred unit for GSR is in terms of log conductance change and this unit seems to have gained a fairly wide acceptance. These workers broadly agree with Haggard (1945) on the criteria for examination of the possible units; relative simplicity of transformation and minimum likelihood of computational errors, comparability of scores between subjects in the same experimental situation and among groups of subjects receiving variations in experimental treatments, independence of change or reaction measures (GSR's) from background or general level measures (basal skin resistance or conductance), and scores which lend themselves to treatment by means of the usual parametric techniques. Lacey and Siegel particularly emphasise the fact that scores must not deviate significantly from normality and independence of the reactivity measure as judged by its lack of correlation with basal level. They determined the basal level of resistance and change in resistance following an electric shock in a sample of 92 male subjects and expressed the results obtained in terms of eight possible units; change in resistance (R)m, change in conductance (C)m, percentage change in R, percentage change in C, change in log R, change in log C, log change in C and a unit (H)

proposed by Haggard (1945). This latter measure is expressed by the formula:

$$\frac{\text{log resistance change GSR + k}}{\text{level of skin resistance}} \times 100$$

where k is an empirically determined constant.

In a later paper, Haggard (1949), the disadvantages of this measure are admitted, namely, the difficulty in determinihg the value of k which was found to vary with experimental treatments and from subject to subject, leading to the expenditure of a great deal of time and effort and, secondly, the division of 'log resistance change GSR + k' by the resistance level. In this paper Haggard concludes that "log conductance change best satisfies the criteria of additivity, normality, homogeneity of variances, independence of means and variances, randomness and maximal precision". Lacey and Siegel reach the same conclusion having examined statistically the degree of independence, by lack of correlation of GSR with base level, and normality, by computing the g_1 (skewness) and g_2 (kurtosis) statistics (Fisher, 1938). The results of these computations showed change in R, percentage change in R, percentage change in C, change in log R and change in log C to be unacceptable. Straightforward change in conductance was found to be acceptable and, of course, more convenient to compute than log change in C. A great deal of consideration has been given to this problem in the field of electrodermal phenomena. Other autonomic responses have not received the same attention though of course the same sort of problem exists.

2. Muscle Tension Measures

There are many problems in the accurate quantification of the EMG record. Basmajian (1962, p.38) maintains that both qualitative and quantitative evaluation of the record is essential and that some sort of classification of activity into levels named nil, negligible, slight, moderate, marked and very marked, is the easiest and most reliable. This method, depending as it does on "the trained observer's visual evaluation of results coloured by his knowledge of the technique involved", is not favoured by most researchers and it obviously makes comparison of the results obtained by different laboratories difficult if not impossible. Some sort of objective quantitative technique seems to be called for. The simple counting of spikes is claimed to be a reflection of the amount of muscle activity (Bergström, 1959). Many workers measure the individual amplitudes of many muscle potential spikes and add these up to give a total of electrical activity over a period of time. This is a tedious process particularly when several muscle groups are being sampled and some form of electronic integrator is therefore often employed. These devices depend upon the fact that the voltage across a condenser is the integral of the current flowing into it and many devices employing this principle have been designed.

Data produced by Malmo and reported by Davis (1959) shows that mean EMG amplitude is directly related to dynamometer pull and Lippold (1952) showed that a linear relation exists between the voltage-time integral of the electromyogram and the

isometric voluntary tension in a muscle.

3. Respiration

"Breathing records offer a great challenge to those who try to interpret them, for they are exceedingly sensitive to all sorts of psychological changes; the problem is to get the desired information out of the records". (Woodworth and Schlosberg, 1955). There are three commonly used measures. First, the respiratory cycle time (RCT) - the time from the onset of one inspiration to the onset of the next. This measure is the reciprocal of respiration rate. Secondly, depth of respiration - the peak-to-peak amplitude of the respiratory cycle - which is related to the volume of air breathed. Thirdly, percentage inhalation time (% I or 'I-fraction') - the ratio of the duration of inspiration to the duration of the respiratory cycle (duration of inspiration plus expiration). A related measure which is sometimes reported is the inspiration-expiration ratio (I/E ratio). Woodworth and Schlosberg note that the I/E ratio is not a good measure statistically since it is not good for averaging and changes in I/E ratio are exaggerated compared with related changes in the I-fraction. These writers also give values for the I-fraction in various conditions (e.g., .16 in speech, .30 in attentive mental work, .60+ in excitement, .75 in sudden fright).

Heart rate changes are related to changes in respiration and it is possible that heart rate changes can be effected by induced respiratory changes. The phenomenon of sinus arrhythmia,

increased heart rate during inspiration and decreased rate during expiration, is more evident in children and young adults than in older people and "tends to disappear as the subject passes from a relaxed state to one of high arousal", (Brener, 1967). Interactions between respiration and heart rate may lead to difficulties in interpreting both sorts of data, but Brener maintains that the three measures mentioned above enable possible relationships between heart rate and respiration and between respiration and independent variables to be ascertained using normal statistical procedures. Deane and Zeaman (1958) suggest plotting any or all of the possible respiratory measures against the independent variable to try to bring to light systematic variations.

4. Heart Rate

Heart rate measurements are very popular in psychology probably because they are comparatively easy to obtain. However, the choice of measure and recording instrument has to be considered carefully so that it will yield information which is appropriate to the particular study. Measures of mean heart rate are therefore only likely to be of use when long term effects are being studied and other measures may be more appropriate when dealing with short term changes. There are often wide ranges of variability within and between subjects. Lacey et al. (1953) suggest a method whereby heart rate measures can be compared within and between subjects by converting raw measures to T-scores. Brener (1967) points out that in view of the high variability it is preferable to use the

longest sampling period possible when dealing with long term effects, or alternatively and perhaps better, to carry out a number of short determinations in order to yield a distribution and then to compare distributions of heart rate or inter-beat-intervals (IBI - the reciprocal of heart rate) rather than means.

Short term phenomena are best studied by examining sequential patterns of heart rate changes. Brener quotes the often used method of numbering successive IBI's before and after the onset of a stimulus and plotting these successive IBI's as a function of their order to yield a heart-rate response function. The typical function (Lang and Hnatiow, 1962) shows a brief heart rate increase for four beats or so, then a prolonged decrease for 20 beats after the stimulus. Brener reports that there is strong evidence that the 'peak-to-valley' difference - the difference between the highest and the lowest values of heart rate in the twenty beats following a stimulus - is the most reliable measure of the heart rate response.

Burdick and Scarbrough (1968) report a study which investigated heart rate level and measures of heart rate variability. A linear negative relationship between mean heart rate and the autocorrelation[1] (used as a variability measure - see below) was found. The relationship was stronger in pre- and post-stress conditions than in stress conditions and was found to hold both within a

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[1] Ezekiel and Fox, 1963. The coefficient of autocorrelation is calculated by correlating each item in a series with the next item following it in time in the series.

subject and between subjects. However there seemed to be no relationship between the autocorrelation measure and condition.

Further investigation suggested that autocorrelation was an unstable measurement since it showed "a great deal of unexplainable oscillation". The coefficient of variability (CV) and the coefficient of temporal variability (CVT) showed more consistency - it increased following exercise and showed a more consistent value during recovery periods. Burdick and Scarbrough feel that "it would be premature to assume that heart rate variability is a measure of activation as measured by the EEG". They found no significant relationship between the CVT of heart rate and an "EEG measure of arousal". Unfortunately very little detail of this part of the study is given.

In a further study Burdick (1968) investigated the concurrent validity and test-retest reliability of the CVT. The test-retest reliability was not significant (rho = 0.48, df = 12). The rank order correlation between CVT and 'peak-to-trough' measures was 0.81, (df = 12, $p < .01$), and between CVT and a 'spontaneous burst' measurement (Johnson, 1963) was 0.66 (df = 12, $p < .05$).

Johnson's 'spontaneous burst' measure is computed as follows: A ten minute recording is divided into 5 second intervals; when the fastest HR in one interval is 6 beats (or more) higher than the preceding interval, the spontaneous 'burst' is scored; the sum of all such bursts is the individual's score.

Opton, Rankin and Lazarus (1966) attempted to produce a

heart rate measurement which had substantial correspondence with "other autonomic and psychological measures of arousal", noting that "it would be difficult to sustain a concept of generalised activation without showing that the various indices of activation do indeed rise and fall together". Relationships between heart rate and skin conductance were determined by means of intra-individual correlations, composite correlations across point means and inter-individual correlations across subject means. The heart rate measures used were peak rate (maximum rate during a ten second interval), peak rate smoothed(computation of the moving average of order 3 i.e., each point averaged with the preceding and succeeding points), mean cyclic maxima (heart rate for each beat-to-beat interval preceded and succeeded by longer (slower) intervals averaged over 10 second periods), mean cyclic maxima, smoothed (moving averages of order 3 from the mean cyclic maxima, unsmoothed data). Heart rate curves obtained by both procedures correlated equally well with skin conductance, both measures being taken while the subjects viewed a stressful film. Intra and inter-individual correlations produced low positive correlations. The peak rate method showed the best visual correspondence with the skin conductance curve and with the stressful and non-stressful film episodes. This method apart from saving considerable data processing time is superior to fixed-interval time sampling since the effects of sinus arrythmia may be largely eliminated. Smoothing the data is apparently a worthwhile procedure, in that it results in an increase in the absolute value of the individual correlations between heart

rate and skin conductance.

Lacey (1956) attacks the notion that the problems can be solved by statistical juggling. He feels that such procedures commit a basic error in that they ignore the physiology of the autonomic nervous system. All measuring operations on responses initiated by the system must be affected by one of the main functions of the system, that of maintaining a homeostatic balance. Any activity, excitatory or inhibitory, in the system initiates changes which tend to nullify the activity. This property of the autonomic nervous system is well known and in developing a statistical model which attempts to deal with the measurement of autonomic changes, Lacey takes note of it. Before examining Lacey's proposed solution, it is necessary to look at an important contribution to the solution provided by Wilder (1950) with his "Law of Initial Values" (LIV). This law is usually now stated in the form: The higher the prestimulus level (initial value), the smaller the tendency to rise with exciting stimuli, and the greater the tendency to drop following inhibiting stimuli. The law was discussed and elaborated by Wilder in a later paper. The law deals with the intensity (extent and duration) as well as the direction of response. "With extreme high or low levels" says Wilder, "there is a progressive tendency to 'no response' or to 'paradoxic reactions', i.e., to a reversal of the type of response: rise instead of fall and vice-versa." An interesting point reported by Wilder is that some authors have found the relationship to be logarithmic, i.e., when

the initial value rises in arithmetic proportion, the response rises in logarithmic proportion.

The Law of Initial Value is, as Wilder notes, an empirical law although attempts have been made to uncover a fundamental theory especially in cybernetic terms. Wilder is reluctant to see the law entirely in terms of nervous regulation for he reports that it can "be seen operating in single cells and even parts of cells and in enzyme systems". Wilder is concerned that the implications of the law be fully noted by physiologists, pharmacologists, physicians, psychophysiologists - all workers concerned with the evaluation of responses which are superimposed upon some background or basal level of behaviour, and he examines the law in terms of psychophysics, somatopsychic medicine, psychosomatic medicine and intrapsychic processes. It is not our concern here to examine in detail the possible fundamental theoretical considerations generated by the law but rather to examine the methods of approach to data which are based on or affected by the law.

To return to Lacey's striking contribution to this work: the product moment correlation (r_{XD}) between the prestimulus level (X) and the response to the stimulation (D) gives some idea of the law of initial values and, over a variety of types of response to a variety of stimuli the law holds. r_{XD} gives us the strength of the dependency of the response on the initial or prestimulus level. The slope of the best fit regression line gives us a means of predicting response scores at a probability level specified by the probability for r_{XD}. Lacey is not happy with the use of r_{XD}

and in attempting to solve the problem posed by the law avoids it. The difficulty with r_{XD}, according to Lacey, lies in the calculation of D. If X is the prestimulus value and Y the post-stimulus value then Y = (X + D) or D = (Y - X). Our correlation between prestimulus level and response is then, between X and Y - X, and X is common to both variables. Churchill (1956), in an appendix to Lacey's monograph, shows how this factor may seriously affect our data manipulation. He shows that "correlations between initial level and either percentage or algebraic change are directly a function of the correlation between initial level and stress level and of the variances of those levels." For an algebraic change:

$$r^2_{XD} = \frac{1 - \sigma_Y^2 (1 - r^2_{XY})}{(\sigma_Y^2 - 2r_{XY}\sigma_Y\sigma_X)\,\sigma_X^2}$$

Lacey points out that if $r_{XY} = 0$ and $\sigma_X^2 = \sigma_Y^2$ then r_{XD} will be -0.707. We shall get some correlation of initial level with algebraic change depending upon the relationship of the standard deviations of the two levels. A similar difficulty is presented by percentage change measurements. Lacey also objects to the redundancy involved in computing change scores, pointing out that doing so, for example, in a situation where a group of individuals had the same base level, would give us no more information than from looking at the post-stimulus level itself. The conclusion reached by Lacey is that we should remove the regression of stress (post-stimulus) level on base (prestimulus) level and make no intermediate calculation of change. Lacey's proposed measure of

autonomic reaction is his Autonomic Lability Score:

$$ALS = 50 + 10 \left\{ \frac{Y_Z - X_Z r_{XY}}{(1 - r^2_{XY})^{1/2}} \right\}$$

where X_Z is the individual's standardised initial level

Y_Z is the individual's standardised stress level

r_{XY} is the correlation for the sample between initial and stress levels.

The constants 50 and 10 give the resulting scores in a distribution with a mean of 50 and a standard deviation of 10.

Lacey arrives at this formula from a discussion of the use of regression models. Since it is, if not impossible, at least extremely difficult to present a stimulus repeatedly on the same initial level in an intra-subject study and impossible to attain the same prestimulus level in a group of subjects some sort of transformation has to be carried out in order to compare our measurements. An ideal solution would be to have defined statistical norms for various populations in various situations so that any individual subject's response could be compared with the appropriate distribution and expressed as, say, the number of standard deviations away from the mean response. Regression analysis provides a possible way around the fact that such an ideal is never likely to be attained. "A best-fitting curve in the least-squares sense, relating x-arrays (initial levels) to the means of the Y-arrays (responses), becomes the locus of estimated average percentage or average algebraic changes at varying initial levels,

and the standard deviation about this 'line of regression' is an estimate of the standard deviation for any distribution of responses at any initial level". Of course, certain conditions have to be met; linearity of the best-fit regression curve, homoscedasticity of the curve and normality of distribution. Lacey maintains that regression models employing algebraic or percentage changes frequently violate these conditions.

Wilder (1962) in a paper given at a conference on "Rhythmic functions in the living system" discusses the application of LIV to biological rhythms. The conference produced many interesting approaches and implications arising from the application of LIV, (see below, Block and Bridger (1962)). Wilder emphasises once more the fact that the law is concerned with what the organism does rather than how it does it - an approach which often upsets the physiologist. This approach also brings research in this field closer to cybernetics and to the study of biological rhythms - a study which has also been mainly concerned with 'what' rather than 'how'. An objection to the introduction of LIV into this field is that the law is concerned with the problem of responses to stimuli which is perhaps an unusual way of approaching the study of biological rhythms. The base lines - the prestimulus value of our variates - are moving base lines; they change over time without overt intervening stimulation. The conclusions are inescapable; we have to consider the time function, the effect of the rhythm systems in the organism when dealing with the LIV which leads on to the view that biological rhythms might be looked at from the

point of view of stimulus and response.

Block and Bridger (1962) agree that the correlation coefficient between raw delta (change) data and prestimulus values is not an appropriate expression of the LIV. They are also concerned to show that the "operation of LIV is not readily evident even when it is stated in terms of the regression coefficient". ($-b_{\Delta,pre}$) "The regression is mathematically related to that of stimulus level upon prestimulus level ($b_{stimulus,pre}$) (Garside, 1956) as follows:

$$b_{stimulus,pre} - b_{\Delta,pre} = 1$$

(b is the slope of the least squares regression)".

They believe that this mathematical relationship provides a different view of the function of LIV which may be of importance in understanding the underlying physiological mechanisms.

"As $b_{stimulus,pre}$ falls toward zero it reflects a progressive tendency for stimulus value not to increase with prestimulus value but rather to remain constant. When $b_{stimulus,pre}$ is equal to zero ($b_{\Delta,pre}$ thus equal to -1), this situation is maximal. Stimulus value is invariable and therefore not a function of prestimulus value". Block and Bridger discuss other implications of this relationship but the main point in relation to LIV is that in expressing it in this way one finds that when the operation of LIV is optimal (i.e., when $b_{stimulus,pre} = 0$ and $b_{\Delta,pre} = -1$), or approaching the optimal, little or no relation exists between prestimulus and stimulus values. The factors which determine pre-

stimulus levels determine whether or not there will be a significant statistical relationship between change scores and prestimulus levels and in Block and Bridger's terms this then becomes "a relatively artifactual happenstance". We should therefore concentrate upon the study of stimulus levels rather than change scores and indeed in most behavioural evaluations this is what we in fact do. Again quoting Block and Bridger, "for example, the startle response of the neonate is described in terms of amount of activity elicited by the stimulus regardless of whether the neonate was crying or sleeping before he was startled . . . If autonomic measurements were to be treated in the same manner as behaviour assessment, i.e., in terms of stimulus levels, a more accurate statement of the phenomena should be evident".

Block and Bridger's interesting reformulation in emphasising the importance of stimulus level directs our attention to the stimulus and its importance to the individual. In assessing this in relation to possible theories of activation it reminds us that level of arousal depends upon a number of variables and not just autonomic reactivity. Block and Bridger show that the operation of LIV is not necessarily an all-or-none phenomenon, that as well as autonomic reactivity, variables such as the number and degree of stimulations determine the degree to which the law will operate. A further problem may arise in statistically equating prestimulus levels because responses at one end of a range of values may be quite different from those at the other end. This is a problem which can only be overcome by creating a range of prestimulus

values and testing over that range. Block and Bridger again ". . . if a difference between stimuli is found to vary with pre-stimulus level, the most sensitive test of the difference may exist only for a restricted range of prestimulus values". This conclusion brings us back to the notion of optimum levels of activation (pre-stimulus values of autonomic function?) being related to behavioural efficiency. How can we obtain an adequate picture of an individual's possible range of prestimulus and stimulus levels? The ideal answer is to monitor our psychophysiological variables over an extended period, but having done that we still have to correct our measures for individual differences in range if we are to compare across subjects. In other words we have to correct for variations in range due to physiological and somatic factors which are most probably unrelated to the underlying variable in which we are interested - arousal.

Lykken et al. (1966) provide a possible solution to the range correction problem. This involves obtaining some estimate of the individual's range on any one variable and does not appear to have gained acceptance although Lykken et al. show that the correction results in very much improved statistical relationships.

Which data transformations and manipulations does the investigator choose? Certainly the variety which are available, all of which are supported and most of which are arguable, leaves him with a problem. In many cases limited time and resources govern the choice, though the increasing availability of sophisticated equipment for data collection and reduction is increasing the range

of choice. In the present case it was decided to use only the simplest and/or most useful transformations, as shown by previous volume of research. If these did not look 'promising' then further more complicated transformations would be attempted. The 'autonomic lability score', although it has not gained wide acceptance has been investigated and has, in the present writer's view, been presented by Lacey in such a thoughtful and challenging way that it seemed too compelling to be ignored. The next chapter describes the experimental part of this study and the data manipulations used are described therein.

IV THE EXPERIMENT

INTRODUCTION

The aim of the study was to try to establish which, if any, of the physiological and personality indices used might be usefully employed as predictors of level of activation. A small set of comparatively easily-measured scores on performance tasks was chosen as the criterion of level of activation. Reliability of the indices had to be established if possible, together with the shape of the distributions of the indices and their inter-relationships. Two main methods of analysis were chosen. Firstly, factor analysis; this has become a general term for a number of procedures designed to analyse intercorrelations in a set of variables. It is concerned with assessing the 'basic structure' of the set, and in the case of principal components analysis, determining the minimum number of dimensions which are needed to account for most of the variance in the set of variables. This procedure was employed to determine whether or not a general performance factor might be present in the range of tasks employed in the experiment and also to assess possible intercorrelations between physiological indices measured, as far as possible, under similar resting conditions. This latter analysis might help to ascertain the presence or absence of a general 'physiological' factor. If a performance factor and a physiological factor were established together with evidence for a strong relationship

between the two, then further analysis to determine the existence and extent of a 'general' activation factor could be carried out. Since previous studies have indicated low or zero correlations between physiological indices, the possibility of this approach bearing fruit seemed unlikely. Nevertheless the evidence for the existence of a relationship between physiological indices and a variety of performance measures is fairly substantial and this relationship had to be explored.

The second procedure employed was multiple correlation analysis, a means of assessing the relationship between one criterion or dependent variable and a set of predictor or independent variables. In this case each of the performance task scores was taken in turn as the criterion variable and put into the multiple prediction analysis with associated physiological variables. The coefficient of multiple correlation (R) is related both to the intercorrelation of the predictor variables and to the correlation of each of these with the criterion variable. The fact that R increases as the size of the predictor-criterion correlations increases and as the size of the inter-predictor correlations decreases is the reason why this method of analysis was chosen. If intercorrelation showed a general lack of relationship between the physiological variables, multiple correlation would nevertheless indicate their contributions to performance variations.

These two procedures, it was hoped, would bring out the possible inter-relationships between the physiological and

performance variables. However a third possibility was explored, the method of canonical correlation. Koons (1962) describes the method, which was developed by Hotelling, for determining the "most predictable criterion", a procedure which "makes it possible to determine the maximum correlation between a set of predictor variables and a set of (rather than a single) criterion variables." The advantages of the method are also described by Koons. A composite criterion is not required and "the sets of variables being studied do not have to conform to the predictor-criterion model." Koons maintains that "the multiple correlation found by this method may be interpreted as is any R." This is not in fact the case. Stewart and Love (1968) point out that canonical correlations cannot, unfortunately, be interpreted as correlations between sets of variables because "whereas a squared multiple correlation represents the proportion of criterion variance predicted by the optimal linear combination of predictors, a squared canonical correlation represents the variance shared by linear composites of two sets of variables, and not the shared variance of the two sets." This diminishes the usefulness of canonical correlation as an analytic index, for as Stewart and Love also say, "it is important to note that a relatively strong canonical correlation may obtain between two linear functions, even though these linear functions may not extract significant portions of variance from their respective batteries." These authors have devised a summary index - the mean squared multiple correlation - which may help with this problem. However since

this latter index was not going to provide more information regarding the inter-relationships between the variables than the multiple correlations planned, it was not included in the present scheme of analysis, nor was canonical correlation proceeded with in view of the difficulties in interpretation.

The question arises as to whether the use of these multivariate methods is a defensible procedure since admittedly it smacks of a 'suck-it-and-see' approach. As Koons has said, "the temptation of a data-engulfing computer is hard to resist." However, the same author admits that "selection of the appropriate multivariate method for a given problem can be determined only through empirical evaluation." The present author admits to a lack of statistical sophistication and a meagre knowledge of the theory behind these approaches. Attempts to improve this knowledge within the field of multivariate analysis exposes one to the controversy which exists there regarding the validity of the various procedures. A general concern of experimental psychologists must be in the search for methods which are mathematically defensible within the whole domain of statistics even though most workers are here in the hands of the statisticians. The acid test for the experimentalist here must surely rest upon whether or not the methods yield results which are capable of psychological interpretation, and which offer the possibility of generating testable hypotheses. When such an outcome is obtained the researcher then commits himself to the procedure he has used.

PROCEDURE

Each subject attended sessions on three successive days at the same time of day. Each session, including subject preparation, experimentation and recording, lasted for approximately one hour.

The following variables were used:

1. Basal conductance (BC) of the palmar skin measured during each of the three sessions and recorded via two electrodes placed on the palm of the subject's non-dominant hand. Units of measurement: millimicromhos.
2. Mean conductance change (MCC) calculated by measuring the change in conductance of each galvanic skin response and taking the mean. MCC was calculated for the 'non-specific' or 'spontaneous' (i.e., occurring in the absence of an observable external stimulus) responses recorded during the initial rest period of each session, and during other periods (to be defined later). Specific responses to a warning light presented during a reaction time task were also measured. Units of measurement: millimicromhos.
3. The number of spontaneous responses (No. GSR) (see above) was recorded.
4. The latency of each of the specific responses was measured and a mean calculated. (Mean latency). Units of measurement: seconds.
5. Respiration rate (RR) measured during the first two sessions. Units of measurement: cycles per minute.

6. Inspiration/Respiration ratio (I/R) The ratio of the duration of an inspiration to the duration of the respiratory cycle in which it occurs taken as a percentage. Measured from the respiration record.
7. Heart Rate (HR) measured during the last two sessions. Units of measurement: beats per minute.
8. Integrated electromyogram taken from the forehead - frontalis muscle - (EMG1), the neck - left sternomastoid muscle - (EMG2), and the non-dominant upper arm - biceps muscle - (EMG3), measured during the last two sessions. Units of measurement: arbitrary units based upon the number of chart divisions of pen deflection weighted according to the sensitivity of the amplifier at the time of recording.
9. Eyeblink rate (EBR) measured during Sessions One and Three. Units of measurement: blinks per minute.
10. Figure reversal rate (FRR) measured at the beginning and end of Session One ($FRR1_1$ and $FRR1_2$) and similarly in Session Three ($FRR3_1$ and $FRR3_2$). The number of times the subject pressed a counter-activating key in response to seeing a reversal of a Necker cube during a two minute exposure period.[1] Units of measurement: responses per minute.
11. Threshold recognition score (Threshold Score) measured in Session One. The mean of the minimum exposure durations necessary for the subject to recognise three simple geometric figures. Units of measurement: scale units (1 scale unit = 5.4 milliseconds, see below).

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1 From this count a score measured in responses per minute was calculated by dividing by two. An 'overall' Figure Reversal Rate mean (again measured in responses per minute) was obtained by calculating the mean of the rates observed at each of the four measurement periods.

12. Word recall score (Recall Score) measured in Session One. The number of correctly recalled and nearly correctly recalled words (i.e., differing only in part of speech e.g., 'fork' for 'forked' would be scored ½) on presentation of a stimulus word, the stimulus-recall pairs having been previously exposed during a learning session. (The lists are given in Appendix 3).

13. Mean of the best ten reaction times (Best 10 RT) measured during Session Two. The mean of the best ten reaction times in a trial series of fifty. In the case of ties for the time ranked tenth in the selection only one time was included.[1] Units of measurement: milliseconds.

14. Pursuit rotor tracking. Time on target (Tracking score) measured during Session Three. The time the subject managed to keep the flexible tip of a stylus in contact with a target during five minutes of rotary pursuit. Units of measurement: seconds.

15. N scale score (N score).The score on a scale of neuroticism - stability calculated from the responses to certain questions in the P.E.N. (psychoticism, extraversion, neuroticism) Inventory.[2] Taken in Session Three.

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[1] This follows Corteen's (1967) procedure of selecting the fastest times and Cowles' (1970) finding of a stronger relationship between the best reaction times and a measure of activation level (basal conductance) than the mean reaction time and the same measure.

[2] These scales have a direct relation with the E and N scales of the M.P.I. and the E.P.I. (Eysenck 1953, 1956) and may be interpreted similarly. The author thanks Dr. G.S. Claridge who supplied copies of the inventory.

16. E scale score (E score). The score on a scale of extraversion-introversion calculated from responses to certain questions in the P.E.N. Inventory. (The full P.E.N. Inventory is given in Appendix 4).

Further details on the measurements of some of these variables is given in the section on Data Extraction below.

Subjects

The subjects were 68 male volunteers aged between 17 years and 34 years (Mean 20 years, standard deviation 3.5).[1] With three exceptions they were all university students or senior schoolboys. The three exceptions were friends of students. The subjects were obtained by direct approach or from replies to notices posted around the University and all the senior schools in the city. Only the briefest details of the experiments, that it involved recording physiological indices "like respiration", and that they were absolutely painless and harmless, were given at the first contact.

Only male subjects were used for a variety of reasons. A minor reason was the possible technical difficulty involved in fixing the electrodes to the arms of girls wearing dresses with sleeves which would not roll up. Removing make-up in order to

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[1] Originally the sample consisted of 72 subjects but four were eliminated due to apparatus breakdown or failure to complete the sessions.

site the forehead electrodes also might have presented problems. More important are the known sex differences in cognitive abilities and in physiologic responses. The former are usually attributed to child-rearing practices, cultural rewards and the like accorded to the two sexes (Anastasi, 1958). Females appear to be better than males in tasks requiring rapid, skilful repetition, small muscle movements, simple perceptual-motor co-ordinations and so on. Broverman et al.(1968) maintain that, in fact, these differences are due to basic physiological processes, reflecting "differences in relationships between adrenergic activating and cholinergic inhibitory neural processes, which, in turn, are sensitive to the gonadal steroid 'sex' hormones, androgens and oestrogens." There is no doubt that hormonal changes during the menstrual cycle may affect many of the physiological indices used in activation research. Hemphill (1942), for example, has shown that menstruating women show abnormally high skin resistance levels. The introduction of these additional variables, which would be very difficult if not impossible to control, might have affected the data considerably and female subjects were therefore not used.

Apparatus

All recordings were taken when the subject was sitting in an 8' x 8' x 6' sound-attenuated cubicle, on a comfortable padded chair. A plug panel near the subject enabled the electrode leads to be kept reasonably short and therefore manageable.

The physiological indices were recorded on a Beckman

Type R Dynograph recorder with four channels, fitted with Dynograph amplifiers Type 482 and pre-amplifiers Type 481B. One channel of an Ediswan Mark I EEG machine was used for recording eye-blinks.

Skin resistance was recorded via two Beckman Biopotential Skin electrodes[1] (the perforated plastic disc which normally covers the electrode surface was removed), one placed in the mid-line of the palm, the other towards the thenar eminence (see Fig. 1, page 112). The centres of the electrodes were 13/16 inches apart. A third ground electrode was placed on the forearm. The electrode sites were cleaned with 'Phisohex' (Bayer Products Co.), the electrode cups filled with Offner paste and the electrodes attached with double adhesive collars. Current across the electrodes was provided from a 4.05 volt Mallory mercury cell. A Beckman Skin Resistance Coupler Type 9829A was the input circuit to the amplifiers. This is essentially a ratio Wheatstone bridge device by means of which, the subject's resistance can be balanced by a ten-turn potentiometer which provides a reading of that resistance.

The Electrocardiogram (EKG) was recorded via two similar electrodes placed one on each wrist of the subject - the standard EKG Lead I position - and a Beckman cardiotachometer coupler Type 9857.

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[1] Miller (1968) describing a method for preparing a silver-silver chloride disc electrode which is extremely precise (essential when skin potential is being measured), reports that the Beckman electrode used in the present study "is quite suitable for general skin conductance and resistance recording . . ."

Respiration was recorded using a very flexible rubber tube, ¼ inch internal diameter, attached to two small pieces of wood, which in turn provided an anchorage for tapes by means of which the lightweight tube was placed around the upper part of the subject's chest. The tube was attached to a Statham Pressure Transducer Model PM97 which was connected to a Beckman Strain Gauge Input Coupler Type 9853. This system is very sensitive and enables respiration to be recorded without any clothing other than the jacket having to be removed and with a minimum of encumbrance of the subject. Subjects soon forgot about the lightweight tube around their chests.

The Integrated Electromyogram was recorded from three sites, again using the Beckman electrodes. The 'upper arm' recording was taken from a standard biceps lead (see Figure 2 page 112) and follows, as do the other leads, with only slight variation, the suggestions of Davis (1959) for EMG electrode placement. The electrode centres were 1½ inches apart and placed over the biceps muscle of the non-dominant limb midway on a line between the anterior fold of the axilla and the cubital fossa. The 'forehead' recording (see Figure 3 page 112) was taken from electrodes placed ½ inch above each eyebrow and half way along it. The 'neck' recording was taken from two electrodes placed over the sternomastoid muscle, the centres 1½ inches apart and the uppermost one below the mastoid process (see Figure 4 page 112). All sites were cleaned using Phisohex and rubbed with Offner paste to reduce skin resistance. The resistance across each of

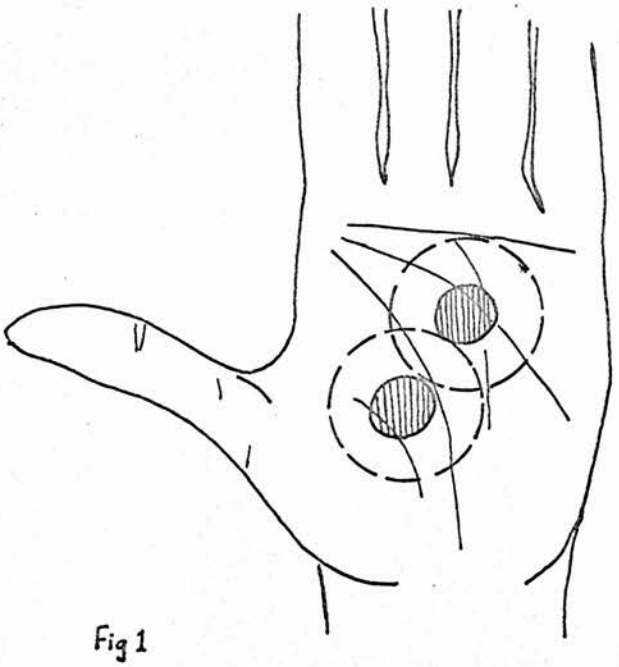


Fig 1

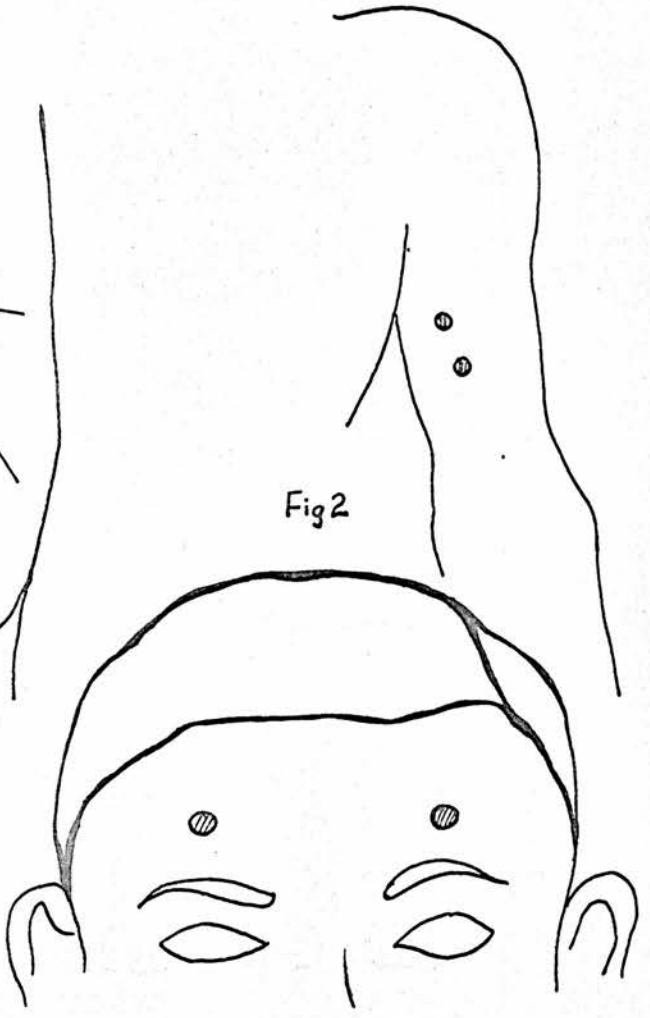


Fig 2

Fig 3.

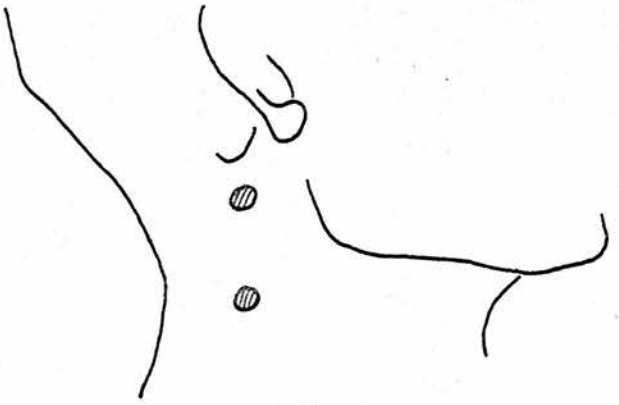


Fig 4

Diagram showing
electrode placements

MUSCLE ELECTRODE SCANNING CIRCUIT

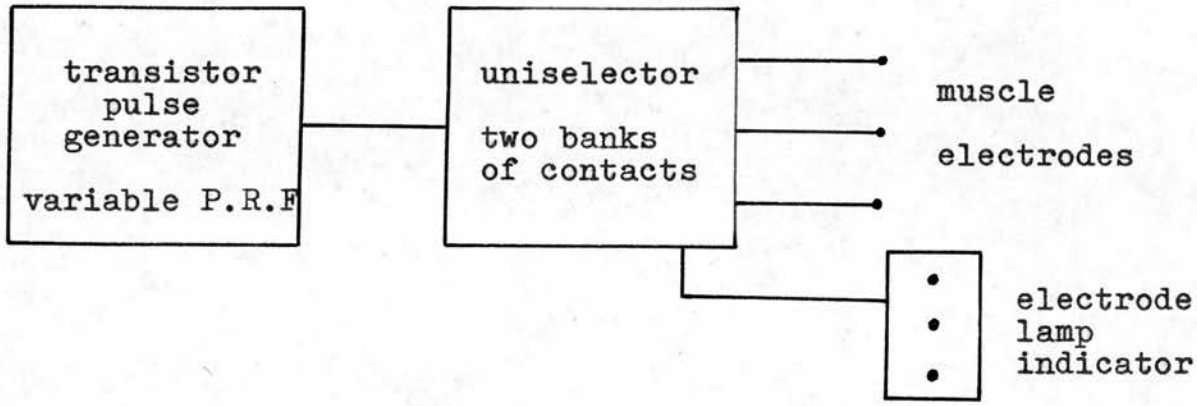
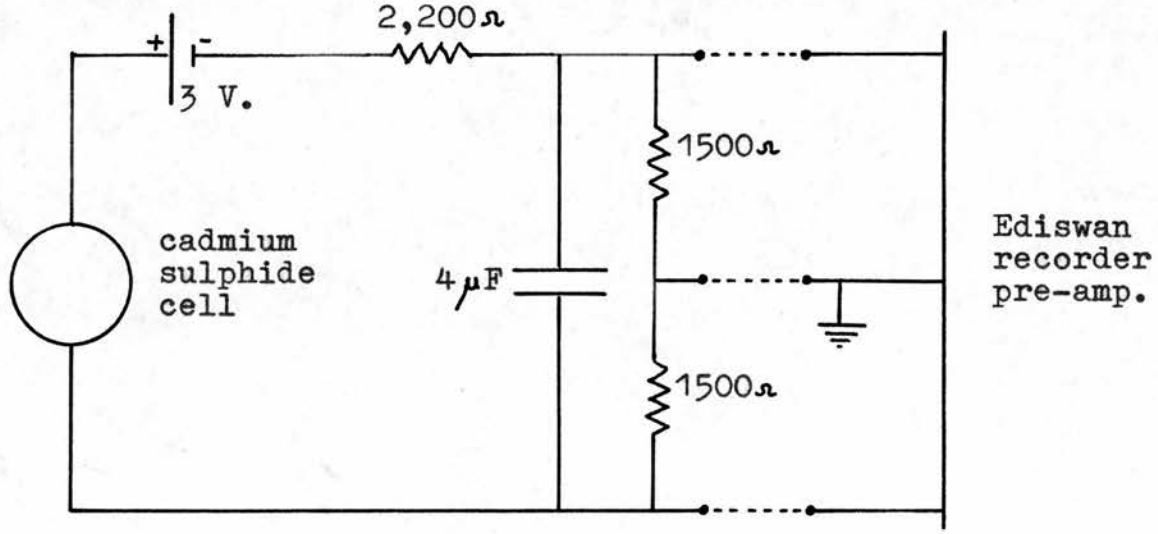


Figure 5

The uniselector consists of two banks of 25 contacts each arranged in an arc of 180°, and wiper assembly. The wiper being double ended ensures that each contact is made sequentially and in continuous rotation without any break. The contacts were divided into groups and strapped together so that three pairs of electrodes could be connected to the uniselector and fed sequentially into one channel of the recording polygraph. One bank of the uniselector was connected to a lamp indicator unit, and showed at any time which electrode position was in use.



EYE BLINK INPUT CIRCUIT Figure 6

the pairs of electrodes was measured, a resistance of five thousand ohms or less being considered satisfactory. Because of the limitation imposed by having only one recording channel available for EMG recording, a uniselector switch circuit (see Figure 5 page 113) switched in each pair of EMG electrodes in turn, for a period of five seconds, to the input of a Beckman EMG integrator coupler Type 9852.

A note on EMG recording

Several unavoidable factors in the situation make the EMG data in this study somewhat unsatisfactory.

The cubicle in which the subject sat during the recording was not electrically shielded. Although a great deal of care was taken to shield all power cables and all apparatus which the subject used and where this was not possible recordings were not taken, such a procedure can never be as satisfactory as an efficient shield. A series of tests was made, putting resistances across the EMG inputs and examining the pen response - the integrated 'signal' - with all apparatus switched on. Below 5000 ohms the deflection was less than three arbitrary units at maximum sensitivity and the response was linear up to at least 20,000 ohms.

Limitations on recording channels available meant that output from all three sites had to be recorded successively on one channel. The same limitation meant that no spare capacity was available to monitor direct EMG continuously, so that it was impossible to keep a close check on possible record artefacts due to electrical interference.

There was little or no problem in reducing skin resistance at the forehead or neck sites and only in one or two cases was it necessary to rub electrode paste into the sites for more than a minute or so. Placing the electrodes at these sites presented no difficulty and it was found to be comparatively easy to reposition them in the same place on the second occasion. The upper arm sites were more difficult, resistance across the electrodes was very high sometimes and rubbing, even with very fine sandpaper, did not always produce a satisfactory level. It was decided not to burr the skin with an electrical burr since this procedure is often unacceptable to many subjects. On those occasions when resistance was higher than usually acceptable, it was measured at intervals through the session and the record assessed taking into account the previously ascertained response to a resistance of equivalent magnitude placed across the input. This is not an entirely satisfactory procedure

and could well have led to error. Repositioning of the upper arm electrodes at the third session on the same sites used in the second session was also difficult. Lippold (1967) reports that "at a given tension . . . the integrated electrical activity recorded from triceps muscle in a human subject showed a 60% difference in level when the distal electrode was shifted laterally by 0.5 cm." In the present study care was taken to ensure that the electrodes were repositioned exactly using surface landmarks, but in the case of the upper arm the skin and underlying muscle bellies are able to move with relation to each other rather easily and unless limb posture is reproduced exactly errors may arise here. Indeed, changes in limb posture alone can produce changes in the integrated activity level, as muscle contraction force is obviously related to the muscle/skeleton lever system. Fixing the limb appears to be the only way to overcome the difficulty, which apart from being a rather difficult task is unacceptable to many subjects and certainly uncomfortable for any worthwhile period of time.

The observations made by Daniel (1949) on Meyer's (1949a) study of reaction time and muscle tension suggest that his recordings were affected by artefacts and though these objections were refuted by Meyer (1949b), they do at least illustrate the difficulties in this area.

Although the results obtained in the present study do not prima facie appear to support the view that artefacts affected the measurements obtained, any conclusions drawn must be tempered with the knowledge that this was possible. Supporting evidence obtained under more acceptable electrical conditions needs, ideally, to be gathered.

Eyeblinks were recorded by means of a photoelectric cell (photoresistive cadmium sulphide cell Mullard ORP12) mounted on a spectacle frame and connected to a bridge circuit (Fig. 6 page 113) which fed the recorder. Eyeblinks produced sharp 'blips' on the record (See Fig. 1, Appendix 5).

Recognition threshold was measured using a Behaviour Apparatus tachistoscope with a modified and more reliable timing unit. The patterns used in the experiment were, a solid black circle 1 cm. in diameter, a solid black square of side 1 cm. and a solid black triangle, height 1 cm.. The resting fixation target was an upright cross of two fine lines each 1 cm. long

intersecting at right angles. Threshold scores were recorded in scale units. Tests using a photoelectric switching device and an Advance Counter-Timer showed that one scale unit (an indicated one millisecond) was a 'true' 5.4 milliseconds. This conversion was based on 100 observations at each of the scale positions used in the experiment.

Paired Adjective Learning The last thirty pairs of adjectives in the list prepared by Melton and Safier and reported by Hilgard (1951) were typewritten, photographed and each pair in turn mounted as a 2 ins. x 2 ins. transparency slide. The first member of each pair was mounted on a separate set of slides. (The words and the order of presentation are given in Appendix 3). The slides mounted in cassettes were projected on to the wall of the cubicle by means of a Zeiss-Ikon Ikomat automatic projector which could be controlled from outside the cubicle.

Reaction Time In front of the subject was a small table on which was mounted an 11 ins. x 5 ins. black perspex panel set at an angle of 20° to the horizontal and raised 2½ ins. from the table surface at its lowest point. Set in the centre of the panel was a black 'reaction' button 5/16 in. in diameter. 2 ins. above this was a yellow lamp and 1 in. above the yellow lamp, a red neon lamp, both lamps being ½ in. in diameter. The yellow lamp served as a 'ready' signal and the red lamp as the reaction stimulus. Outside the cubicle the experimenter's control panel enabled a foreperiod of 1, 2, 3, 4, or 5 seconds

to be selected. After selecting a foreperiod the experimenter pressed an activating switch which illuminated the yellow lamp and simultaneously started the foreperiod timing operation (controlled by a C-R time constant circuit of the appropriate value for the desired foreperiod). The same switch activated a marker-pen on the Beckman recording chart. At the end of the foreperiod the red light was automatically illuminated and simultaneously, an electronic timer (Electrophysiological Apparatus Ltd and supplied with 1000 Hz from a Siemens-Ediswan oscillator Type R666) capable of reading from 0 to .999 seconds, started. Pressing the reaction button stopped the timer and extinguished the reaction lamp.

Pursuit Tracking A Koerth type pursuit rotor constructed in the Department of Psychology was used. This consisted of a black perspex disc 11 ins. in diameter with a 1 in. diameter brass target set 1 in. from the edge. A stylus 13 ins. in length, fitted with a plastic handle and having a 4 ins. flexible tip set at right angles to the end was used for tracking the target. Contact between the tip of the stylus and the target completed a circuit which activated an Advance Counter-Timer (Type SC1) outside the cubicle and enabled time on target to be recorded. The rotor was set up on the table before the subject at an appropriate distance and angle. For the grosser timing a Smith's clockwork stop-clock was used.

Figure Reversal Rate was measured using a Necker cube of side length 6 ins. drawn on a card 12 ins. square, mounted on a rod

6 feet away from the subject approximately at head height. A small fixation cross was drawn in the centre of the cube. The rod extended through the wall of the cubicle and by turning it the experimenter was able to expose either the cube or a blank white card to the view of the subject. When the subject pressed a morse-type key (on seeing a reversal) a circuit was made to an electromagnetic counter outside the cubicle which kept a tally of the number of times the key was pressed.

Detailed Procedure

Because of the difficulty of satisfactorily shielding the tachistoscope and its timing box, the threshold experiment was carried out outside the special cubicle and no physiological recording was carried out during it. The use of an automatic slide projector presented the same difficulty in the paired associate learning task and there was, therefore, no physiological recording during either the learning or recall periods. During this experiment the subject was in the cubicle and isolated from the experimenter, though the door was ajar during the recall period so that the experimenter could hear the subject's responses.

Session 1 On arrival at the laboratory the subject was shown the recording apparatus and it was explained to him that the aim of the research was to record and measure physiological indices, "for example, heart rate and respiration," before, during and after a series of simple tasks, "for example, a tracking task." The subject was shown the electrodes and the method of attachment and

assured that there would be no electric shocks, and that he would not be asked to undergo any painful or harmful procedure. The importance of attending for all three of the sessions was stressed and it was suggested that if, now that he knew a little of what he was required for, he felt that he might not attend all three sessions, then he should not start. All the subjects agreed to continue and none showed alarm or anxiety at the array of recording apparatus.

The subject was then asked to seat himself before the tachistoscope and to look into its viewer at the upright cross. They were asked not to fixate the cross, but merely look down the viewing tube for a few minutes "so that they might get used to the dimmer illumination." After five minutes the procedure was explained thus:

"Right, now keep on looking down the tube; (the square was inserted in the card holder and exposed for 80 scale units) Did you see a square? (The answer was always in the affirmative and this procedure was repeated for the circle and the triangle). O.K., a square, a circle and a triangle. Now I am interested in finding out what the briefest exposure time is, at which you can recognise a square, a circle and triangle. This apparatus - a tachistoscope - allows me to expose those patterns for very brief intervals of time. This is what I shall do, I shall say 'Ready', and immediately flash the tube and I want you to tell me if you see a square, a circle or a triangle. Only one of the patterns will be shown at any one time. If the flash is so fast that you don't see anything or if you're not sure which pattern it is, just say 'No'. I shall say

'Ready' and flash the tube and you say 'square', 'circle' or ' 'triangle' depending on which you see, or, if the exposure is too brief, or you're not sure, you say, 'No'. O.K.?"

None of the subjects had any questions about this procedure and the experiment was carried out as follows. Starting with an exposure time of 10 scale units the three patterns were shown in a random fashion. Exposure times were varied from 10 scale units to 1 scale unit but with a decreasing trend until a minimum time was established where on at least six exposures the subject was correct on at least three occasions. This minimum time was established for each of the three patterns. This experiment lasted approximately 15 minutes. The subject was then told that just three electrodes were to be attached, two to the palm of his non-dominant hand and one to the corresponding forearm. While these electrodes were being fitted the subject was told, "Tomorrow when you come you will have more electrodes attached to you but this will give you some idea of what it is like." The electrodes were attached as shown in Figure 1 and a ground electrode attached to the forearm. Five minutes after the palmar electrodes were fitted the subject was taken into the cubicle and the electrode leads plugged into the wall panel. The respiration chest belt and the eyeblink recorder were fitted. The instructions were as follows:

"For the first few minutes all I want you to do is to relax, relax and look ahead at the white card. This will allow you to settle down and my apparatus to settle down also. After

these few minutes I shall turn the card over and you will see the cube - thus. Now this figure, as you may have noticed already, is a reversing figure. When you look at it there are two possible 'perspectives', two 'orientations'. Sometimes this face (indicated) appears to be at the front and the cube is oriented this way, (indicated), sometimes this face (indicated) seems to be at the front and the cube is oriented this way (indicated). Now, when I turn the card over and you see the cube, fixate the cross in the centre of the cube, look steadily at the cross in the centre of the cube and if you see it reverse and every time you see it reverse, press this key. The key is connected to a counter which will record the number of times you see the cube change. When I turn the card back - thus - so that it is as you see it now, relax and look ahead at the white card, O.K.?" All the subjects indicated that they were able to see the two 'orientations' of the cube and understood the instructions.

The doors of the cubicle were closed and the recording apparatus switched on for five minutes, recording respiration, skin resistance and eyeblink. After five minutes the Necker cube was exposed for two minutes.[1]

The recording apparatus was placed on stand-by and the

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[1] In the case of subjects who normally wore glasses, the experimenter entered the cubicle at the end of the five minute recording period to allow the subject to exchange the eye-blink recording device for his glasses, so that the cube could be clearly seen. He was, of course, told at the start of the recording period that this would be done.

experimenter entered the cubicle saying, "That was fine, now the next part of the experiment is a relatively simple learning task. I will project on the wall here (indicated) using this automatic projector a series of slides. On each slide is a pair of words, in fact a pair of adjectives. I want you to read the words carefully and I want you to try to remember them, in fact I want you to learn them. When we have gone through the list I shall, after we have done a little more recording, test you by giving you the first member of each of the pairs and asking you to call out the second member. A series of slides, on each slide a pair of words which I want you to learn. Each slide will be shown for 15 seconds. I should tell you that the order of presentation of the single words in the test will not be the same as the order of presentation of the pairs of words. Do you understand?" Many subjects asked how many pairs of words there would be and these were always answered with "Quite a few".

The clock was started and the series of slides was presented in the order given in Appendix 3, each slide being shown for exactly fifteen seconds. (There was a two second interval between exposures, this being the time the automatic changer took to operate.) Ten seconds after the last fifteen-second exposure the projector was switched off, the subject was told to relax and look ahead at the white card and thirty seconds after the last exposure the recording apparatus was switched on recording respiration, skin resistance and eyeblink as before. Four minutes later the recording apparatus was switched to stand

by, the projector switched on, and the subject told, "I shall show you each of the first members of those pairs for ten seconds. If you can remember its partner call it out". Exactly 5 minutes after the last pair had been shown the first single-word slide was exposed for ten seconds. The series was shown in the order given in Appendix 3 and a note taken of the subject's reponses. At the end of the series (after the final ten second exposure) the projector was switched off and the experimenter entered the cubicle saying, "That was fine, now just relax for a few minutes and look ahead at the white card. Once again, in a minute or two, I shall show you the cube and once again every time you see it reverse, press the key. When I turn the card back so that it is as you see it now, relax, and look ahead at it". Forty-five seconds after the last ten-second exposure the recording apparatus was re-started and two minutes post-recall recording obtained. The Necker cube was then exposed once more for two minutes, after which the apparatus was shut down and the cubicle re-entered. The eyeblink recorder and respiration belt were removed and the electrode leads disconnected. The subject then left the cubicle, the electrodes were removed and the electrode paste removed from his skin. He was reminded of his appointment for the following day and the session was over.

Session 2 On arrival the subject was reminded that a number of electrodes would be fitted that day and the positions of the sites were indicated. The electrode sites were cleaned and prepared and the electrodes applied (as previously stated and see Figures 1-4). The respiration chest belt was fitted. After a final check on

EMG electrode resistance the subject was taken into the cubicle and the leads plugged into the wall panel. When the subject was comfortable he was asked to relax "for the first few minutes just as you did yesterday" and to "look ahead at the white card".

The doors of the cubicle were closed and the recording apparatus switched on for five minutes, recording respiration, integrated EMG, successively from the three sites, electrocardiogram and skin resistance.

The recording apparatus was placed on stand-by and the experimenter re-entered the cubicle. The reaction time apparatus was briefly described and the following instructions given: "This is a reaction time experiment. Sit with your forefinger on the button and watch for the yellow light. This is your 'get ready' light. A short time after the yellow light comes on, the red light will come on . This time is variable, but as soon as the red light comes on, press the button. Release it after a moment or two and wait for the next trial. O.K.?

"In order to give you some incentive, you'll be paid on a sliding scale according to your speed. For every reaction time of less than 0.2 seconds you'll be paid 3d, between 0.2 and 0.225, 2d, 0.225 to 0.25, 1d, and slower than 0.25 seconds, nothing. It is possible to earn over twelve shillings but most people get something between six and ten shillings. The faster you are the more you'll be paid."

A series of fifty trials at foreperiods ranging from one to five seconds was presented. The foreperiod times were randomised

over the fifty trials, each foreperiod being used on ten occasions. Presentation of the warning stimulus was determined by the pen recording skin resistance having reached a reasonably steady base line, the coupler bridge being rebalanced when necessary as the experiment continued. The experimenter recorded each reaction time on a prepared sheet.

At the end of the series the experimenter shut down the apparatus, re-entered the cubicle, disconnected the electrode leads and checked EMG electrode resistance once again. The electrodes were then removed, the subject told that he would be paid on the following day, and the session was over.

Session 3 On arrival the subject was told that electrodes were to be fitted as in the previous day's session. The electrodes were fitted as before and EMG electrode resistances checked. The subject entered the cubicle, was again asked to relax for the first few minutes but told that as in Session 1, the cube reversal rate was to be measured. The procedure followed that of Session 1 precisely. At the end of the Necker cube exposure the experimenter entered the cubicle and set up the tracking apparatus. The following instructions were then given. "In a few moments I shall call out 'Ready - begin', when I say 'begin' I want you to try to track the target with the stylus thus (the method of tracking was demonstrated). I am able to record how long you are able to keep the stylus in contact with the target and I want you to do your best not to lose contact. Notice that if you press too hard the stylus will slide away because of the flexible tip." The position

of the apparatus was adjusted on the subject's instruction to what he considered to be the best position for him, but no practice was allowed. The experimenter left the cubicle and switched on the recording apparatus and timer. After checking that all was well with the recordings the experimenter called out, "Ready - begin," closed the doors of the cubicle quietly and continued the recording for exactly 5 minutes from the time of saying 'Begin'. Time on target for the 5 minute session was noted. At the end of the tracking period the door of the cubicle was opened, the subject was asked to stop and allowed to relax for 5 minutes. The subject was then asked once again to co-operate in a further measure of reversal rate, the instructions being precisely the same as before. At the end of this final two minute Necker cube inspection period, the subject left the cubicle and the electrodes were removed. The subject was then asked to complete the P.E.N. Inventory (Appendix 4), the instruction to work quickly was emphasised and most subjects completed the questionnaire in about ten minutes. The subject was then paid for his reaction time performance, thanked for his co-operation and the series was over. (In fact, no subject was given less than 7/- no matter what his performance. This was done in order that the schoolboy subjects in particular would not be deterred from volunteering for other projects in the Psychology Department.) In all cases subjects were asked not to discuss the experimental sessions with other possible subjects. There was no evidence that this request was not followed.

DATA EXTRACTION

Basal Conductance For each of the five minute rest periods at the beginning of each recording session basal resistance was noted at the start of the period and thereafter at one minute intervals. Each reading was converted to millimicromhos and the mean of these six figures gave Mean basal conductance level (BC1, BC2 and BC3). Similarly, the first two minutes post-learning, first two minutes post-recall, reaction time task, and pursuit rotor tracking task periods yielded resistance level readings at the start of each period and thereafter at one minute intervals. Again a conversion to conductance units was carried out and the mean calculated in each case giving BCPL, BCPRcl, BCRT and BCT.

Galvanic Skin Responses A count was made of the number of non-specific responses occurring during each of the three five minute rest periods. For each response, the drop in resistance was measured and the change in conductance calculated from the formula:

$$\frac{r \times 10^6}{R\,(R - r)}$$

where r = drop in resistance in kilohms

R = 'basal' level immediately prior to response in kilohms

This gives the conductance change in millimicromhos and from each set obtained a mean was calculated giving the various MCC's. Similar measures were taken for the post-learning and post-recall periods. Mean conductance changes to the specific stimulus of the warning light presented during the reaction time task were also calculated and a count was taken of the number of responses elicited. For the calculation of the mean, n was the total number

of possible responses, i.e., 50.

The time between the presentation of the warning light and the onset of each specific response was measured - the latency of the response - and for each subject a mean latency was calculated.[1] Respiration Rate (RR) was measured during the periods indicated merely by counting the number of respiratory cycle peaks occurring in that period and calculating a mean in cycles per minute. An adequate measure of RR during the reaction time task proved to be impossible because of the tendency of many subjects to hold their breath when the warning light appeared. See Figure 7 Appendix 5. Inspiration/Respiration Ratio (I/R) as a percentage was calculated from the mean of the eleven respiratory cycles starting from the first one at the beginning of the five minute rest periods and thereafter at half minute intervals in Sessions 1 and 2. Figure 7 shows the periods of the cycle which give the ratio. The post-learning and post-recall periods yielded similar measurements,

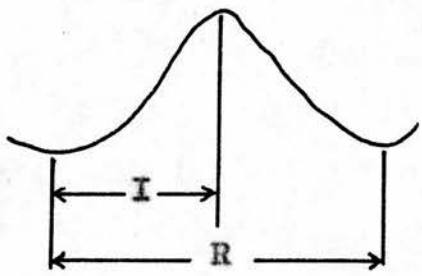

Figure 7

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[1] Because the marker and recording pens were not exactly in line the indicated latencies shown in Table D7 Appendix 1 should be reduced by 0.6 seconds to give a 'true' reading.

five in each case, again taken at the beginning of the period and then at half minute intervals. During the twenty second period following the subject being told of the reaction time task, the mean I/R as a percentage was calculated from all the cycles observed in that period.

Heart Rate (HR) was measured by counting the number of R waves in the EKG record which occurred during the periods indicated and calculating a mean in beats per minute. Accurate counting of R waves during the reaction time and pursuit rotor tasks proved to be impossible in many cases. A frequent but not universal finding was a marked fluctuation of the 'base-line' which sometimes obliterated the EKG wave form. Figure 3 Appendix 5 is a section of record showing a drifting base-line.

Integrated Electromyogram (EMG) was read directly from the chart for the periods indicated having applied the appropriate amplifier sensitivity correction and, on occasion, resistive factor correction and means calculated.

Eyeblink Rate (EBR) was measured during the periods indicated by counting the number of eyeblink 'blips' occurring during the period and converting to a mean blinks per minute score. Figure 1 Appendix 5 shows a section of eyeblink record. Once again, certain difficulties led to the data being not as complete as the writer would have wished. During the post-learning and post-recall periods many subjects, despite instructions to the contrary, took the opportunity of looking around the cubicle. The resulting head-movements and large eye-movements seriously affected the recording.

RESULTS

The data as prepared for the computer is shown in Appendix I. A selection of frequency distributions of this data is given in Appendix II. This section includes complete results tables and preliminary and general comments on them. Detailed comments on important results are reserved for Chapter V.

Table R.1 shows the means and standard deviations of this data. Table R.2 shows the test-retest reliability coefficients for the resting physiological variables and Autonomic Lability Scores.

In all cases ** indicates significance at or beyond the .01 level of confidence, *, the .05 level.

The factor analyses were computed using the University of Miami Biometric Laboratory program FACTOR and run on a Univac 1108 machine.

The multiple correlation analyses were computed using the Edinburgh Regional Computing Centre program MULTREG with AUTOMATIC ELIMINATION and run on an English Electric KDF9 machine.

Interpretation of the Factor Analyses

There seems to be no generally accepted method of assessing the significance of factor loadings.[1] Kerlinger (1964)

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[1] Signs of factor loadings. The sign of a factor loading is to some extent arbitrary though loadings of opposite signs on a particular factor may reflect the direction of correlation coefficients in the correlation matrix. Experience with the FACTOR program has shown that the signs are also a function of the machine on which this program is run, for variations are sometimes found. This makes the interpretation of the signs of the loadings rather difficult.

TABLE R1 Means and Standard Deviations

DESCRIPTOR		VARIABLE	MEAN	STANDARD DEVIATION
'PERFORMANCE' (TABLE D1)	1	Mean of the best ten reaction times (Best 10 RT).	214.4956	17.6493
	2	Standard Deviation of reaction time (S.D.RT).[1]	40.5544	12.3580
	3	Pursuit rotor tracking. Time on target (Tracking Score).	81.0456	63.6336
	4	Word recall score (Recall Score).	13.3456	5.7829
	5	Threshold scores (Threshold Score).	3.4824	0.8494
	6	N Scale scores (N Score).	9.6618	3.9648
	7	E Scale scores (E Score).	13.2941	3.8013
	8	Overall mean figure reversal rate (Overall FRR).	15.2838	8.0885
'PHYSIOLOGY ONE' (TABLE D2)	1	Mean basal conductance level. Session Two (BC2)	6866.4970	5214.8756
	2	Number of galvanic skin responses. Session Two (No.GSR2)	10.9118	11.0355
	3	Mean conductance change. Session Two (MCC2)	345.6911	539.3786

1 This score is the standard deviation of the distributions of each subjects set of fifty reaction times.

TABLE R1 cont. Means and Standard Deviations

DESCRIPTOR		VARIABLE	MEAN	STANDARD DEVIATION
'PHYSIOLOGY ONE' (TABLE D2)	4	Mean integrated electromyogram level recorded from forehead. Session Two (EMG1.2)	11.1324	7.1954
	5	Mean integrated electromyogram level recorded from neck. Session Two (EMG2.2)	18.1912	9.1989
	6	Mean integrated electromyogram level recorded from upper arm. Session Two (EMG3.2)	17.8897	8.5107
	7	Mean heart rate. Session Two (HR2)	75.6456	11.5390
	8	Mean respiration rate. Session Two (RR2)	15.7338	3.0479
	9	Mean inspiration/respiration rate. Session Two (I/R2)	37.2500	5.0708
	10	Mean eyeblink rate. Session One (EBR1)	15.2103	9.2742
'PHYSIOLOGY TWO' (TABLE D3)	1	Mean basal conductance level. Session Three (BC3)	6155.9029	3359.6964
	2	Number of galvanic skin responses. Session Three (No.GSR3)	12.6471	10.9569

TABLE R1 cont. Means and Standard Deviations

DESCRIPTOR		VARIABLE	MEAN	STANDARD DEVIATION
'PHYSIOLOGY TWO' (TABLE D3)	3	Mean conductance change. Session Three (MCC3)	318.0705	306.5002
	4	Mean integrated electromyogram level recorded from forehead. Session Three (EMG1.3)	10.1103	6.3545
	5	Mean integrated electromyogram level recorded from neck. Session Three (EMG2.3)	14.5588	7.6756
	6	Mean integrated electromyogram level recorded from upper arm. Session Three (EMG3.3)	15.4265	10.7652
	7	Mean heart rate. Session Three (HR3)	75.1735	10.1594
	8	Mean respiration rate. Session One (RR1)	16.1074	3.0595
	9	Mean inspiration/respiration ratio. Session One (I/R1)	38.8382	4.3249
	10	Mean eyeblink rate. Session Three (EBR3)	15.7132	10.1551
'THRESHOLD' (TABLE D4)	1	Mean basal conductance level during first five minutes (BC1)	5249.7500	2600.9500

TABLE R1 cont. Means and Standard Deviations

DESCRIPTOR		VARIABLE	MEAN	STANDARD DEVIATION
'THRESHOLD' (TABLE D4)	2	Number of galvanic skin responses during first five minutes (No.GSR1).	15.2059	12.5740
	3	Mean conductance change during first five minutes (MCC1).	229.7390	201.3770
	4	Mean respiration rate during first five minutes (RR1).	16.1074	3.0595
	5	Mean inspiration/respiration ratio during first five minutes (I/R1).	38.8382	4.3249
	6	Mean eyeblink rate during first five minutes (EBR1).	15.2103	9.2742
	7	Mean figure reversal rate (first period) (FRR1)	14.2941	7.2360
	8	Threshold score (Reversed Threshold Score).[1]	6.5177	0.8494
'WORD RECALL POST-LEARNING' (TABLE D5)	1	Mean basal conductance level two minutes post-learning (BCPL).	8308.8200	3945.9600
	2	Number of galvanic skin responses two minutes post-learning (No.GSRPL).	8.3971	6.3649
	3	Mean conductance change two minutes post-learning (MCCPL).	381.7060	288.7110

1 Scores on the threshold task were 'reversed' by subtracting each score from ten. This results in high scores being 'good'.

TABLE R1 cont. Means and Standard Deviations

DESCRIPTOR		VARIABLE	MEAN	STANDARD DEVIATION
	4	Mean respiration rate two minutes post-learning (RRPL).	15.8971	3.3161
'WORD RECALL POST-LEARNING' (TABLE D5)	5	Mean inspiration/respiration ratio two minutes post-learning (I/RPL).	36.9265	4.8294
	6	Mean eyeblink rate during first five minutes (EBR1)	15.2103	9.2742
	7	Mean figure reversal rate (first period) ($FRR1_1$).	14.2941	7.2360
	1	Mean basal conductance level two minutes post-recall (BCPRc1).	9177.3500	4553.7900
	2	Number of galvanic skin responses two minutes post-recall (No.GSRPRc1)	7.7941	5.8732
'WORD RECALL POST-RECALL' (TABLE D6)	3	Mean conductance change two minutes post-recall (MCCPRc1).	474.4690	454.6440
	4	Mean respiration rate two minutes post-recall (RRPRc1).	15.4779	3.1687
	5	Mean inspiration/respiration ratio two minutes post-recall (I/RPRc1).	36.5882	4.9482

TABLE R1 cont. Means and Standard Deviations

DESCRIPTOR	VARIABLE	MEAN	STANDARD DEVIATION
'WORD RECALL POST-RECALL' (TABLE D6)	6 Mean eyeblink rate during first five minutes (EBR1)	15.2103	9.2742
	7 Mean figure reversal rate (second period ($FRR1_2$).	15.1029	8.9249
'REACTION TIME' (TABLE D7)	1 Mean basal conductance level during reaction time task (BCRT).	8121.1500	4012.5500
	2 Number of galvanic skin responses to the warning light (No.GSRWL).	32.6618	12.0591
	3 Mean conductance change to the warning light (MCCRT).	347.4350	292.2730
	4 Mean respiration rate in twenty second period after S told of RT task (RRRT).	17.8676	3.4937
	5 Mean inspiration/respiration ratio in twenty second period after S told of RT task (I/RRT).	38.7794	5.2911
	6 Mean heart rate in twenty second period after S told of RT task (HRRT)	84.6618	12.9461
	7 Mean integrated electromyogram level recorded from forehead during RT task (EMG1RT).	12.5000	6.7570

TABLE R1 cont. Means and Standard Deviations

DESCRIPTOR		VARIABLE	MEAN	STANDARD DEVIATION
'REACTION TIME' (TABLE D7)	8	Mean integrated electromyogram level recorded from neck during RT task (EMG2RT).	20.0735	11.0600
	9	Mean integrated electromyogram level recorded from upper arm during RT task (EMG3RT).	21.8676	11.3964
	10	Mean latency of galvanic skin response to the warning light (Mean latency).	2.4054	0.2378
'TRACKING' (TABLE D8)	1	Mean basal conductance level during pursuit rotor tracking (BCT).	7934.0100	3617.9200
	2	Heart rate in twenty second period after S told of tracking task (HR(T))	77.4412	12.0030
	3	Mean integrated electromyogram level recorded from forehead during tracking (EMG1(T)).	12.6691	8.7151
	4	Mean integrated electromyogram level recorded from neck during tracking (EMG2(T)).	19.4559	10.5635
	5	Mean integrated electromyogram level recorded from upper arm during tracking (EMG3(T)).	20.6397	12.2297

TABLE R2 Reliability Coefficients

VARIABLE	SESSIONS WHEN MEASURED	PEARSON r
BC	One,Two	0.682**
BC	Two,Three	0.785**
BC	One,Three	0.658**
MCC	One,Two	0.335**
MCC	Two,Three	0.463**
MCC	One,Three	0.257*
No. GSR	One,Two	0.659**
No. GSR	Two,Three	0.606**
No. GSR	One,Three	0.544**
HR	Two,Three	0.769**
RR	One,Two	0.661**
I/R	One,Two	0.503**
EMG1	Two,Three	0.501**
EMG2	Two,Three	0.490**
EMG3	Two,Three	0.402**
EBR	One,Three	0.637**
FRR	One (1,2)	0.802**
FRR	Three (1,2)	0.919**
FRR (Mean 1 & 2)	One,Three	0.866**
ALS (Conductance)	Two,Three	0.376**
ALS (Heart Rate)	Two,Three	0.252*

reports that some workers set 0.3 as an arbitrary level and others 0.4, and presumably ignore, or treat with caution, lower loadings. Other workers interpret them in much the same way as the Pearson product-moment coefficient of correlation. Harman (1960) outlines a procedure for approximating very roughly the standard error of a set of factor loadings. Each of these procedures gives different criterion levels. One can quite deliberately choose a level which, as it were, provides the most evidence for what one is trying to show. Cooley and Lohnes (1962) mention briefly the procedure for estimating the approximate standard error and also comment upon the lack of agreement on the problem of how many factors to preserve for further analysis after a principal components analysis. "Statistical considerations alone are not completely satisfactory, since the number of significant factors then depends on the the size of the sample. (Even the 'inveterate statistician' who insists on tests of significance can be frequently caught making arbitrary decisions on the significance level in order to include or exclude a particular factor!)". In the present study, it was decided to extract factors which in total would 'account for all the variance' and to unashamedly interpret them in terms of the significance or otherwise of the coefficients in the correlation matrix, the reasonable expectations of which variables ought to 'go together', and the size of the factor loadings.

Since the ultimate aim of the study was to ascertain which, if any, of the physiological measures might be used as predictors of performance, the Varimax rotation was employed after

a principal components analysis, for the Varimax solution has the advantage that the resulting factors tend to be "invariant under changes in the composition of the test battery" (Kaiser, 1958). This means that small changes in the battery of variables chosen would not or should not affect the basic results. The Varimax rotation attempts to simplify the columns of a factor loadings matrix i.e., to simplify the factors. The rotation might therefore make the factors easier to interpret, however, as Cooley and Lohnes (1962) point out, "The nature of the Varimax criterion is such that general factors, if originally present in the principal component solution, tend to be 'destroyed' during rotation."

Armstrong and Soelberg (1968) have examined a number of studies which have employed factor analysis and have reached some depressing conclusions. Few of the studies have included either a reliability or a validity measure and some have included neither. These writers make a number of suggestions to workers using factor analytic approaches, including where possible the use of an 'a priori' analysis with predictions based on 'behavioural models', literature search, intuitions and educated guesses. As far as validity is concerned, they suggest the specifying of one dependent variable which the factor analysis is designed to help explain or predict.

In this study two analyses of physiological variables, measured on separate occasions, have been carried out in the hope that an assessment of reliability can be made. The analysis of performance variables is necessarily more difficult to assess for

reliability and the battery of measures are in the main the criterion variables for main analysis.

Testing significance for intercorrelations

"Tracing relationships among variables is the legitimate business of the scientist, but simply asking if anything relates linearly to anything else in a large set of variables is a pretty crude way to do business" (Hays, 1963).

The first step in either a factor analysis or a multiple correlation analysis is of course the construction of a correlation matrix. If then a test of significance is carried out on each of the $\binom{K}{2} = \frac{K!}{(K-2)! \cdot 2}$ coefficients (where K is the number of variables), the results obtained can be misleading if not meaningless since each of the correlation coefficients is not based on a different sample. As Hays points out, "one should ordinarily expect more than $\binom{K}{2}\alpha$ such tests to show significance by chance alone . . . The values of intercorrelations are dependent upon each other in a given sample . . . . One should either not test for significance in the ordinary way in dealing with intercorrelations found for a single sample, or he should interpret the significance levels with considerable latitude".

Having said this the writer, has in fact marked those correlations 'significant' at the .05 and .01 levels which appear in the correlation matrices on the following pages and has listed

and charted later in the chapter, a summary of these 'significant' correlations. This is not a flagrant disregard of the assumptions and conditions of significance testing, but has been done to highlight those correlations which are higher than average and more important to follow an inter-relationship through over the experimental sessions. If a relationship is replicated on a separate occasion there are grounds for accepting it, if it is not then the 'considerable latitude' clause of Hays' remarks should apply. It might be worth mentioning too, that in each matrix a good many more 'significant' relationships than would be expected by chance were in fact found.

First Factor Analysis 'PERFORMANCE'

Included in this analysis was a 'derived variable', standard deviation of reaction time, to examine the possibility that this measure of variability might be associated with the personality dimension scores. Although the 'E' and 'N' scores and overall mean figure reversal rate are intended as 'predictor' variables it is difficult to immediately include them with the physiological measures which as far as possible were recorded simultaneously with each other. If a further 'excuse' is needed for including them here then all these measures, like the strict performance variables, were taken when the subject was 'doing something'. Consideration of the correlation matrix (Table R3a) indicates that the decision to include the 'derived' variable and the strictly-speaking 'non-performance' variables, was

justified since each of these variables correlates significantly with at least one of the performance variables (Mean of the best ten reaction times, Pursuit Rotor time on target, Word Recall score and Threshold score).

The Principal Components analysis (Table R3b) indicates that the first factor accounting for over twenty-eight per cent of the variance is an overall performance factor with high loadings on perceptual-motor skills, learning and personality stability. The second factor which brings the percentage of the variance accounted for to almost forty-five might be described in terms of a 'cortical inhibition' factor along Eysenckian lines, since on the one hand Threshold score and on the other Mean figure reversal rate and 'E' dimension score provide the significant loadings. The next three factors between them accounting for very nearly a further thirty-eight per cent of the variance are not of immediate concern but might be tentatively labelled as 'Performance - personality', 'Performance - variability' and 'Personality' respectively. In total these factors account for almost eighty-three per cent of the variance.

The Varimax rotation (Table R3c) shows very clearly how this procedure simplifies factors. The first factor can be very definitely labelled 'Perceptual-motor skill' and the remaining columns each now having had the variance 'evened-out' amongst them show high loadings for each of the remaining variables in turn.

All in all, the results of this analysis without the need for sophisticated examination are very much as one would

TABLE R3a Correlations 'PERFORMANCE'

	1	2	3	4	5	6	7	8
1 Best 10 RT	1.0000							
2 S.D.RT	0.1181	1.0000						
3 Tracking Score	-0.5919**	-0.2454*	1.0000					
4 Recall Score	-0.2869*	-0.1190	0.3782**	1.0000				
5 Threshold Score	0.1559	-0.0613	-0.0053	-0.1687	1.0000			
6 N Score	0.1246	0.0378	-0.2815*	-0.5195**	0.0935	1.0000		
7 E Score	-0.0988	0.0680	-0.1058	-0.2926*	0.0109	0.0919	1.0000	
8 Overall FRR	-0.1076	-0.0916	0.0954	0.1224	-0.3178*	-0.0825	0.0667	1.0000

TABLE R3b 'PERFORMANCE'

	PRINCIPAL COMPONENTS							
	1	2	3	4	5	6	7	8
	EIGENVALUES							
	2.284	1.298	1.222	0.985	0.829	0.637	0.426	0.319
	PERCENT OF VARIANCE							
	28.553	16.229	15.271	12.314	10.366	7.961	5.324	3.982
	FACTOR LOADINGS							
1 Best 10 RT	0.652	-0.178	-0.510	0.250	-0.296	0.015	0.109	-0.348
2 S.D.RT	0.314	0.180	-0.362	-0.753	0.253	0.323	0.011	-0.050
3 Tracking Score	-0.761	-0.133	0.403	-0.070	0.151	0.165	0.269	-0.336
4 Recall Score	-0.764	-0.187	-0.343	-0.079	-0.075	-0.038	-0.477	-0.151
5 Threshold Score	0.289	-0.670	0.377	-0.047	-0.294	0.463	-0.127	0.082
6 N Score	0.606	0.159	0.365	0.281	0.528	0.072	-0.286	-0.174
7 E Score	0.233	0.505	0.504	-0.346	-0.503	-0.164	-0.126	-0.144
8 Overall FRR	-0.305	0.672	-0.143	0.379	-0.177	0.507	-0.017	0.044

TABLE R3c 'PERFORMANCE'

VARIMAX ROTATION

	1	2	3	4	5	6	7
PERCENT OF VARIANCE	20.042	12.745	13.405	12.648	13.130	12.523	11.527
ROTATED FACTOR LOADINGS							
1 Best 10 RT	0.879	-0.141	-0.088	-0.006	0.171	-0.008	0.223
2 S.D.RT	0.109	0.036	-0.005	-0.990	-0.030	-0.044	0.044
3 Tracking Score	-0.870	-0.081	-0.261	0.156	0.162	0.070	-0.020
4 Recall Score	-0.218	0.073	-0.314	0.057	0.190	0.061	-0.885
5 Threshold Score	0.043	-0.979	0.043	0.037	-0.011	-0.162	0.059
6 N Score	0.100	-0.045	0.946	-0.002	-0.015	-0.026	0.248
7 E Score	-0.015	-0.011	0.020	-0.030	-0.978	0.042	0.142
8 Overall FRR	-0.053	0.162	-0.027	0.046	-0.042	0.981	-0.048

expect and indeed see from an 'armchair analysis' of the original correlation matrix. A factor of perceptual-motor skill which is associated with learning ability can readily be identified and there is also support for a perceptual factor which might be identified with the concept of cortical inhibition.

The analysis helps to decide how to arrange the variables for the subsequent multiple correlation analyses and thus far achieves its purpose.

Second and Third Factor Analyses 'PHYSIOLOGY ONE' and 'PHYSIOLOGY TWO'

The first analysis was of the nine physiological variables simultaneously recorded during Session Two plus Eyeblink Rate, recorded in Session One. Table R4a shows the correlation matrix. Significant correlations between Basal Conductance and Mean Conductance Change, between all three EMG measurements, between EMG3 and Eyeblink Rate, between Heart Rate and Basal Conductance, Respiration Rate and Inspiration - Respiration Ratio were obtained. The Principal Components analysis (Table R4b) shows first of all a muscle tension factor (21.64% of the variance) with high loadings on the EMG measures and a moderate loading on Eyeblink Rate. The second component is a more general factor accounting for 19.14% of the variance. It includes substantial loadings on the electrodermal measurements and Heart Rate and moderate loadings on the respiration measures. The third component reflects the same trend. Varimax emphasises

TABLE R4a **Correlations** **'PHYSIOLOGY ONE'**

	1	2	3	4	5	6	7	8	9	10
1 BC2	1.0000									
2 No.GSR2	.1692	1.0000								
3 MCC2	.4876**	.1762	1.0000							
4 EMG1.2	-.0969	-.0965	-.1119	1.0000						
5 EMG2.2	.0601	-.0434	.0063	.5887**	1.0000					
6 EMG3.2	.0844	-.0391	.0742	.4957**	.4619**	1.0000				
7 HR2	.2447*	.1691	.0361	-.1063	-.1094	.0119	1.0000			
8 RR2	.1241	.1096	-.0604	.0094	-.0171	-.0601	.3355**	1.0000		
9 I/R2	.0289	.2247	.0323	.0782	.0804	-.0229	.3675**	.1209	1.0000	
10 EBR1	.1088	.0852	.0710	.2246	.0862	.3066*	.0252	.0628	-.0266	1.0000

TABLE R4b

'PHYSIOLOGY ONE'

	PRINCIPAL COMPONENTS									
	1	2	3	4	5	6	7	8	9	10
	EIGENVALUES									
	2.164	1.914	1.397	1.007	.921	.765	.599	.488	.384	.360
	PERCENT OF VARIANCE									
	21.643	19.144	13.974	10.073	9.213	7.650	5.992	4.876	3.838	3.597
	FACTOR LOADINGS									
1 BC2	-.021	.668	-.482	.054	-.317	-.020	-.030	.389	-.151	-.205
2 No.GSR2	-.143	.527	.008	-.220	.611	-.462	-.253	.017	.037	-.027
3 MCC2	-.034	.509	-.675	-.190	-.097	.022	.238	-.375	.184	.088
4 EMG1.2	.841	-.018	.206	-.069	-.029	-.090	.115	.011	.319	-.350
5 EMG2.2	.787	.075	.057	-.276	-.207	-.240	.035	.204	.002	.390
6 EMG3.2	.780	.164	-.089	.077	-.001	.165	-.375	-.308	-.289	-.057
7 HR2	-.191	.648	.418	.100	-.187	.343	-.332	.024	.286	.118
8 RR2	-.094	.426	.457	.483	-.286	-.444	.194	-.200	-.106	.000
9 I/R2	-.013	.479	.506	-.499	.135	.290	.336	-.017	-.216	-.057
10 EBR1	.403	.259	-.126	.585	.510	.244	.248	.134	.018	.119

TABLE R4c

'PHYSIOLOGY ONE'

VARIMAX ROTATION

	1	2	3	4	5	6
	PERCENT OF VARIANCE					
	20.235	13.411	15.506	11.377	11.097	10.071
	ROTATED FACTOR LOADINGS					
1 BC2	.014	.080	-.857	.197	.055	-.006
2 No.GSR2	-.065	.133	-.139	.079	.075	-.938
3 MCC2	-.017	-.011	-.841	-.179	.012	-.146
4 EMG1.2	.845	.008	.169	.019	.139	.026
5 EMG2.2	.885	-.027	-.064	.015	-.124	-.034
6 EMG3.2	.687	.038	-.140	-.084	.400	.131
7 HR2	-.144	.751	-.178	.389	.121	.103
8 RR2	.005	.101	.004	.945	.009	-.083
9 I/R2	.113	.860	.056	-.083	-.112	-.248
10 EBR1	.128	-.027	-.038	.031	.937	-.087

muscle tension and skin conductance factors.

The form of the 'Physiology Two' analysis follows that of 'Physiology One' save that the variables differed in the times at which they were measured. In this case the respiration measures were those of Session One, the other variables were all taken in Session Three. Table R5a, the correlation matrix, shows similar significant correlations to those in Table R4a except that the correlations between Heart Rate and the respiration measures (in this case measured on different occasions) were not found. Significant correlations not found in 'Physiology One' are those between the number of spontaneous GSR's and Basal Conductance and between Heart Rate and EMG2. Principal Components Analysis (Table R5b) differs from that obtained in 'Physiology One' in some respects though the major component (22.519% of the variance) again shows substantial loadings on the muscle tension measures. This component is not separated in terms of distributions of loadings from the second one in anything like as clear cut a way as the first two in 'Physiology One'. The factors appear to be altogether more general. Surprisingly, Eyeblink Rate in this case measured simultaneously with the EMG measures does not show any loading on components associated with the EMG. The Varimax rotation (Table R5c) shows much more correspondence with that of our second factor analysis, producing a muscle tension and a skin conductance factor which, in both cases, together account for about 36% of the variance.

The last three variables of 'Physiology One' and

TABLE R5a **Correlations** **'PHYSIOLOGY TWO'**

	1	2	3	4	5	6	7	8	9	10
1 BC3	1.0000									
2 No.GSR3	.2670*	1.0000								
3 MCC3	.6433**	.3713**	1.0000							
4 EMG1.3	-.1604	.1836	.0153	1.0000						
5 EMG2.3	-.1705	.1531	-.0575	.5166**	1.0000					
6 EMG3.3	-.0705	.0575	.0823	.5605**	.4370**	1.0000				
7 HR3	.3034*	.1068	.1354	-.1016	-.2906*	-.0753	1.0000			
8 RR1	.1570	.0932	.0831	-.0821	.0066	-.0478	.1919	1.0000		
9 I/R1	-.0415	.1330	-.0454	.0865	.2049	.0456	.1711	.0073	1.0000	
10 EBR3	-.0259	.0241	-.0909	-.0636	-.0713	.0142	.0460	.1470	.0283	1.0000

TABLE R5b

'PHYSIOLOGY TWO'

	PRINCIPAL COMPONENTS								
	1	2	3	4	5	6	7	8	9
	EIGENVALUES								
	2.252	1.984	1.242	1.040	.870	.844	.668	.423	.382
	PERCENT OF VARIANCE								
	22.519	19.841	12.422	10.399	8.700	8.438	6.683	4.232	3.824
	FACTOR LOADINGS								
1 BC3	.573	-.622	.189	-.048	.048	.053	.276	.230	-.020
2 No.GSR3	.046	-.672	-.064	.063	-.491	.011	-.509	-.102	-.151
3 MCC3	.359	-.734	.339	-.070	-.060	.069	.220	-.136	.147
4 EMG1.3	-.723	-.413	-.001	-.048	.203	.084	-.216	.079	.442
5 EMG2.3	-.746	-.320	-.070	-.010	-.160	-.251	.167	.401	-.188
6 EMG3.3	-.633	-.411	.003	-.203	.390	.206	.129	-.298	-.290
7 HR3	.471	-.271	-.423	.273	.538	.155	-.265	.190	-.095
8 RR1	.247	-.218	-.492	-.428	.119	-.657	.017	-.127	.064
9 I/R1	-.155	-.200	-.572	.655	-.184	.015	.332	-.160	.088
10 EBR3	.078	.061	-.579	-.546	-.257	.518	.109	.084	.045

TABLE R5c

'PHYSIOLOGY TWO'

VARIMAX ROTATION

	1	2	3	4	5	6	7
	PERCENT OF VARIANCE						
	19.383	16.930	10.151	10.692	11.419	10.199	10.228
	ROTATED FACTOR LOADINGS						
1 BC3	.117	-.882	.001	-.002	.177	-.094	-.057
2 No.GSR3	-.091	-.242	-.029	.073	.031	-.039	-.942
3 MCC3	-.062	-.893	.057	-.047	.003	.004	-.197
4 EMG1.3	-.846	.121	.078	-.001	-.010	.062	-.223
5 EMG2.3	-.636	.092	.109	.310	-.464	-.160	-.137
6 EMG3.3	-.887	-.094	-.084	-.015	.006	.045	.133
7 HR3	.045	-.138	-.004	.136	.936	-.127	-.051
8 RR1	.039	-.074	-.080	-.012	.095	-.977	-.034
9 I/R1	-.048	.036	-.021	.973	.098	.017	-.061
10 EBR3	.019	.051	-.990	.016	.019	-.078	-.024

'Physiology Two' were omitted and the analyses re-run this time having only variables which were recorded simultaneously included. Tables R4d and R5d show the Principal Components analyses and Tables R4e and R5e the Varimax Rotations. Looking first at the Principal Components analyses, in both cases the EMG measures load the first component substantially, but in the case of 'Physiology Two', Basal Conductance, and Heart Rate provide higher loadings for this factor than are seen in 'Physiology One'. In the 'Physiology Two' analysis, of course, Heart Rate was found to negatively correlate with EMG2 very much more substantially than in 'Physiology One'. If we examine the Basal Conductance and Mean Conductance Change measures we find that they have substantially higher standard deviations in the 'Physiology One' as compared with the 'Physiology Two' data. These standard deviations obtained from data collected in Sessions Two and Three are not so great as those from corresponding data collected in the first session.

The Varimax rotations show a somewhat clearer picture and show substantial similarity.

All in all these analyses provide evidence for first of all, a muscle tension factor. The case for a general autonomic factor appears to be worth further investigation for some relationships between the autonomic variables seem to be present.

Interpretation of the Multiple Correlation Analyses

The aim of linear multiple regression is to obtain

TABLE R4d

'PHYSIOLOGY ONE'

	PRINCIPAL COMPONENTS						
	1	2	3	4	5	6	7
	EIGENVALUES						
	2.069	1.699	.990	.858	.554	.450	.380
	PERCENT OF VARIANCE						
	29.552	24.271	14.145	12.250	7.914	6.436	5.432
	FACTOR LOADINGS						
1 BC2	.119	-.815	.167	.235	.270	-.371	.166
2 No.GSR2	.214	-.453	-.366	-.782	-.022	-.060	.018
3 MCC2	.132	-.736	.493	-.023	-.175	.407	-.038
4 EMG1.2	-.857	-.014	-.116	-.057	.109	.204	.442
5 EMG2.2	-.815	-.190	.005	-.083	.381	.052	-.381
6 EMG3.2	-.736	-.294	-.093	.093	-.541	-.234	-.085
7 HR2	.226	-.406	-.751	.415	.008	.212	-.058

TABLE R4e 'PHYSIOLOGY ONE'

VARIMAX ROTATION

	1	2	3	4	5	6
	PERCENT OF VARIANCE					
	23.193	14.494	14.341	14.335	13.844	14.361
	ROTATED FACTOR LOADINGS					
1 BC2	.003	-.937	-.137	-.073	-.044	.263
2 No.GSR2	.038	-.066	-.081	-.990	.017	.080
3 MCC2	.035	-.249	.004	-.086	-.035	.963
4 EMG1.2	-.831	.180	.000	.055	-.278	-.027
5 EMG2.2	-.900	-.147	.089	.002	-.126	-.019
6 EMG3.2	-.340	-.051	-.015	.017	-.934	.040
7 HR2	.069	-.121	-.985	-.081	-.012	-.002

TABLE 5d

'PHYSIOLOGY TWO'

	PRINCIPAL COMPONENTS						
	1	2	3	4	5	6	7
	EIGENVALUES						
	2.202	1.937	.907	.766	.490	.397	.301
	PERCENT OF VARIANCE						
	31.451	27.666	12.960	10.945	6.998	5.679	4.303
	FACTOR LOADINGS						
1 BC3	.550	-.660	.063	-.280	.225	.035	-.358
2 No.GSR3	.026	-.670	.229	.663	-.167	-.158	-.069
3 MCC3	.337	-.779	.220	-.284	-.107	.095	.360
4 EMG1.3	-.741	-.392	-.227	.056	-.134	.466	-.091
5 EMG2.3	-.763	-.268	.162	.065	.546	-.078	.111
6 EMG3.3	-.660	-.400	-.317	-.333	-.226	-.373	-.056
7 HR3	.468	-.245	-.790	.222	.181	-.017	.123

TABLE R5e 'PHYSIOLOGY TWO'

VARIMAX ROTATION

	1	2	3	4	5
	PERCENT OF VARIANCE				
	23.070	23.755	14.792	14.718	13.684
	ROTATED FACTOR LOADINGS				
1 BC3	.145	-.890	-.236	.049	.018
2 No.GSR3	-.058	-.220	-.052	.954	.079
3 MCC3	-.114	-.884	.045	.231	-.107
4 EMG1.3	-.793	.121	.013	.220	.289
5 EMG2.3	-.344	.067	.169	.084	.907
6 EMG3.3	-.911	-.073	.037	-.085	.118
7 HR3	.031	-.129	-.972	.049	-.139

from recorded data an equation of the form:

$$y = b_o + b_1x_1 + b_2x_2 + \ldots + b_nx_n$$

y is the dependent or criterion variable.

$x_1, x_2 \ldots, x_n$ are the independent or predictor variables. In addition to the mean and standard deviation of each variable and its maximum and minimum values, output from this program includes, for each of the independent variables, the coefficient, its standard error, and the modulus of the t value. The value of the constant term is calculated, and its standard error. The percentage of the total residual explained by the regression equation, the Snedecor F - value and the corresponding value of the F - (variance ratio) distribution function and R, the multiple correlation coefficient are given.

Darlington (1968) discusses the use of multiple regression in psychology. He examines, among other problems, the difficulties in assessing which variables appear to be the 'best' and which should be retained in the analysis. The process of AUTOMATIC ELIMINATION used in the present study seems to be an efficient and legitimate procedure for exhaustively examining the usefulness of the independent variables as predictors. The equation is tested for significance at the 10% probability level. If it is not significant the elimination is terminated. If it is significant Student's t for each variable is tested for significance at the 10% level, and all variables which are not significant are removed from the regression. The equation is then tested again at the 10% level and if there has been a significant

change in the residual, the removed variables are re-entered one at a time to find which contributes most to the regression. The best variable is re-entered and the regression equation again tested at the 10% level. Variables continue to be added until the regression equation is significant, at which stage it is printed out. The reduction is repeated at the 5%, 1% and 0.1% significance level. If however the equation before reduction to a subsequent level is not significant at that level the elimination is terminated.[1]

Guilford (1956) points out that the multiple R may be an inflated value since "it capitalises upon any chance deviations that favour high multiple correlation". For samples of less than 100 Guilford gives this formula which is "a common way of 'shrinking' R to a more probable population value":

$$_cR^2 = 1 - (1 - R^2)\,\frac{(N - 1)}{(N - m)}$$

where N = number of cases in sample correlated.

m = number of variables correlated.

This correction has been applied to the values obtained in the following analyses.

First Multiple Correlation Analysis 'THRESHOLD'

This analysis is of the resting physiological variables measured in Session One plus the mean Figure Reversal Rate

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[1] The analysis used in the automatic elimination is as used in the BISRA program for Multiple Regression Analysis by Robinson and Taylor OR/CA/39/65.

TABLE R6a Correlation Matrix 'THRESHOLD'

1	BC1	1						
2	No.GSR1	0.160	2					
3	MCC1	0.439**	0.413**	3				
4	RR1	0.167	0.176	0.083	4			
5	I/R1	0.003	0.091	0.042	0.007	5		
6	EBR1	-0.031	0.196	0.099	0.191	-0.155	6	
7	$FRR1_1$	0.346**	-0.053	0.107	0.199	0.016	-0.188	7
8	Reversed Threshold Score	0.440**	-0.146	0.164	-0.078	-0.222	-0.177	0.240*

Scores on the threshold task were 'reversed' by subtracting each score from ten. This procedure results in high scores being 'good'.

TABLE R6b Regression Equation 'THRESHOLD'

	Variable	B-Coefficient	Standard Error of B	t ratio	Degrees of freedom	Residual Sum of Squares	Residual Mean Squares
8	Reversed Threshold Score				67	4.8339×10	7.2147×10^{-1}
8	Reversed Threshold Score				60	3.2519×10	5.4198×10^{-1}
1	BC1	1.3858×10^{-4}	4.1057×10^{-5}	3.38			
2	No.GSR1	-1.1674×10^{-2}	8.1303×10^{-3}	1.44			
3	MCC1	3.1160×10^{-4}	5.4089×10^{-4}	0.58			
4	RR1	-3.1049×10^{-2}	3.1410×10^{-2}	0.99			
5	I/R1	-4.5621×10^{-2}	2.1237×10^{-2}	2.15			
6	EBR1	-1.2607×10^{-2}	1.0473×10^{-2}	1.20			
7	FRR_1	8.9750×10^{-3}	1.3844×10^{-2}	0.65			
	CONSTANT	8.2315	9.7186×10^{-1}				

$F = 4.1700$ $P = 8.4648 \times 10^{-4}$

$R = 0.5721^{**}$ 32.73% explained

Corrected $R = 0.499^{**}$

TABLE R6c Elimination 'THRESHOLD'

Variable	B	SE(B)	t	DF	Res SS	Res MS
10.0% Significance Level						
8 Reversed Threshold Score				65	3.6555×10	5.6238×10^{-1}
1 BC1	1.4405×10^{-4}	3.5225×10^{-5}	4.09			
5 I/R1	-4.3847×10^{-2}	2.1184×10^{-2}	2.07			
CONSTANT	7.4644	8.4759×10^{-1}				
				$F = 1.0477 \times 10$		$P = 1.1377 \times 10^{-4}$
				$R = 0.4937^{**}$		24.38% explained
				Corrected $R = 0.470^{**}$		
5.0% Significance Level	NO CHANGE					
1.0% Significance Level						
8 Reversed Threshold Score				66	3.8964×10	5.9037×10^{-1}
1 BC1	1.4382×10^{-4}	3.6090×10^{-5}	3.98			
CONSTANT	5.7626	2.1114×10^{-1}				
				$F = 1.5880 \times 10$		$P = 1.7117 \times 10^{-4}$
				$R = 0.4404^{**}$		19.39% explained
0.1% Significance Level	NO CHANGE					

measured in the first period of Session One as predictor variables and the 'Reversed' Threshold Score as criterion.

Table R6a shows the correlation matrix. Once again Mean Conductance Change correlates both with Basal Conductance level and number of responses. Basal Conductance level correlates significantly with the criterion - Reversed Threshold Score - and with Figure Reversal Rate which correlates at the .05 level of confidence with the Threshold Score.

Table R6b shows the coefficients of the regression equation and the Multiple R together with its corrected value both of which are significant beyond the .01 level of confidence.

Table R6c shows the results of the elimination. Basal Conductance level is retained as the best predictor to the .001 significance level. Testing the equation to the 5% level retains Inspiration/Respiration Ratio. In fact the correlation of this variable with the criterion falls short of significance at the .05 level but its higher t-ratio ensures that this variable is retained whereas Figure Reversal Rate, though this does correlate with the criterion, is eliminated because of its low t-ratio.

Second and Third Multiple Correlation Analyses 'WORD RECALL POST-LEARNING' and 'WORD RECALL POST-RECALL'.

These analyses include the Post-Learning and Post-Recall physiological variables, the Eyeblink Rate measured during the Session One rest period, the mean Figure Reversal Rates for both periods in Session One, the N and E scale scores

TABLE R7a Correlation Matrix 'WORD RECALL POST-LEARNING'

1	BCPL	1								
2	No.GSRPL	0.263*	2							
3	MCCPL	0.453**	0.414**	3						
4	RRPL	0.058	-0.104	-0.087	4					
5	I/RPL	0.063	-0.027	-0.183	-0.034	5				
6	EBR1	-0.063	0.177	-0.084	0.200	-0.025	6			
7	$FRR1_1$	0.384**	-0.198	0.240*	0.047	-0.047	-0.188	7		
8	N Score	-0.068	0.037	0.140	0.049	0.211	-0.010	-0.007	8	
9	E Score	-0.203	0.010	0.111	0.161	-0.011	0.059	-0.002	0.092	9
10	Recall Score	0.257*	0.013	-0.168	0.020	-0.075	-0.025	0.109	-0.520**	-0.293*

TABLE R7b Regression Equation 'WORD RECALL POST-LEARNING'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
10	Recall Score				67	2.2406×10^{3}	3.3442×10
10	Recall Score				58	1.3253×10^{3}	2.2850×10
1	BCPL	3.6802×10^{-4}	1.9725×10^{-4}	1.87			
2	No.GSRPL	9.4459×10^{-2}	1.1271×10^{-1}	0.84			
3	MCCPL	-5.3952×10^{-3}	2.7263×10^{-3}	1.98			
4	RRPL	7.8488×10^{-2}	1.8858×10^{-1}	0.42			
5	I/RPL	-4.8227×10^{-2}	1.3109×10^{-1}	0.37			
6	EBR1	-2.3899×10^{-2}	6.7190×10^{-2}	0.36			
7	$FRR1_1$	6.6353×10^{-2}	9.5951×10^{-2}	0.69			
8	N Score	-6.5041×10^{-1}	1.5733×10^{-1}	4.13			
9	E Score	-2.6954×10^{-1}	1.6608×10^{-1}	1.62			
	CONSTANT	2.1370×10	6.0342				

F = 4.4510 P = 1.8479×10^{-4}

R = 0.6392** 40.85% explained

Corrected R = 0.563**

TABLE R7c Elimination 'WORD RECALL POST-LEARNING'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
	10.0% Significance Level						
10	Recall Score				64	1.4101×10^{3}	2.2033×10
1	BCPL	5.0270×10^{-4}	1.6481×10^{-4}	3.05			
3	MCCPL	-5.1862×10^{-3}	2.2695×10^{-3}	2.29			
8	N Score	-6.7102×10^{-1}	1.4771×10^{-1}	4.54			
	CONSTANT	1.7632×10	1.9958				
					F = 1.2564×10	P = 1.4787×10^{-6}	
					R = 0.6088^{**}	37.06% explained	
					Corrected R = 0.584^{**}		
	5.0% Significance Level	NO CHANGE					
	1.0% Significance Level						
10	Recall Score				65	1.5252×10^{3}	2.3465×10
1	BCPL	3.2655×10^{-4}	1.5032×10^{-4}	2.17			
8	N Score	-7.3566×10^{-1}	1.4961×10^{-1}	4.92			
	CONSTANT	1.7740×10	2.0590				
					F = 1.5245×10	P = 3.7245×10^{-6}	
					R = 0.5651^{**}	31.93% explained	
					Corrected R = 0.546^{**}		

TABLE R7c cont.

	Variable	B	SE(B)	t	DF	Res SS	Res MS
	0.1% Significance Level						
10	Recall Score				66	1.6359×10^{3}	2.4787×10
8	N Score	-7.5772×10^{-1}	1.5341×10^{-1}	4.94			
	CONSTANT	2.0667×10	1.6004				
					$F = 2.4396 \times 10$	$P = 5.6372 \times 10^{-6}$	
					$R = 0.5195^{**}$	26.99% explained	

TABLE R8a Correlation Matrix 'WORD RECALL POST-RECALL'

1	BCPRcl	1								
2	No.GSRPRcl	0.246*	2							
3	MCCPRcl	0.593**	0.328**	3						
4	RRPRcl	0.023	0.112	0.179	4					
5	I/RPRcl	-0.180	-0.096	-0.164	0.071	5				
6	EBR1	-0.065	0.224	-0.010	0.203	-0.015	6			
7	$FRR1_2$	0.413**	-0.206	0.248*	0.047	-0.155	0.028	7		
8	N Score	-0.013	0.185	0.214	0.040	0.054	-0.010	-0.173	8	
9	E Score	-0.213	0.023	0.200	0.185	0.065	0.059	0.043	0.092	9
10	Recall Score	0.256*	-0.153	-0.126	-0.024	-0.273*	-0.025	0.167	-0.520**	-0.293*

TABLE R8b Regression Equation 'WORD RECALL POST-RECALL'

Variable	B	SE(B)	t	DF	Res SS	Res MS
10 Recall Score				67	2.2406×10^{3}	3.3442×10
10 Recall Score				58	1.2163×10^{3}	2.0971×10
1 BCPRcl	4.7655×10^{-4}	1.8752×10^{-4}	2.54			
2 No.GSRPRcl	-1.3861×10^{-1}	1.1400×10^{-1}	1.22			
3 MCCPRcl	-2.8050×10^{-3}	1.7990×10^{-3}	1.56			
4 RRPRcl	1.4730×10^{-1}	1.8656×10^{-1}	0.79			
5 I/RPRcl	-2.8172×10^{-1}	1.1728×10^{-1}	2.40			
6 EBR1	8.7023×10^{-3}	6.4415×10^{-2}	0.14			
7 $FRR1_2$	-4.8007×10^{-2}	7.7068×10^{-2}	0.62			
8 N Score	-6.3136×10^{-1}	1.5049×10^{-1}	4.20			
9 E Score	-1.8590×10^{-1}	1.6943×10^{-1}	1.10			
CONSTANT	2.8575×10	5.7860				

F = 5.4273 P = 2.2026×10^{-5}

R = 0.6761** 45.72% explained

Corrected R = 0.612**

TABLE R8c Elimination 'WORD RECALL POST-RECALL'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
10.0% Significance Level							
10	Recall Score				64	1.4040×10^{3}	2.1937×10
1	BCPRcl	2.6836×10^{-4}	1.2775×10^{-4}	2.10			
5	I/RPRcl	-2.4300×10^{-1}	1.1773×10^{-1}	2.06			
8	N Score	-7.3707×10^{-1}	1.4454×10^{-1}	5.10			
	CONSTANT	2.6895×10	4.8365				

$F = 1.2713 \times 10$ $P = 1.2899 \times 10^{-6}$

$R = 0.6111^{**}$ 37.34% explained

Corrected $R = 0.587^{**}$

5.0% Significance Level NO CHANGE

1.0% Significance Level

10	Recall Score				65	1.4974×10^{3}	2.3038×10
1	BCPRcl	3.1573×10^{-4}	1.2878×10^{-4}	2.45			
8	N Score	-7.5284×10^{-1}	1.4791×10^{-1}	5.09			
	CONSTANT	1.7722×10	1.9553				

$F = 1.6130 \times 10$ $P = 2.0506 \times 10^{-6}$

$R = 0.5759^{**}$ 33.17% explained

Corrected $R = 0.558^{**}$

TABLE R8c cont.

	Variable	B	SE(B)	t	DF	Res SS	Res MS
	0.1% Significance Level						
10	Recall Score				66	1.6359×10^{3}	2.4787×10
8	N Score	-7.5772×10^{-1}	1.5341×10^{-1}	4.94			
	CONSTANT	2.0667×10	1.6004				
					F = 2.4396×10	P = 5.6372×10^{-6}	
					R = 0.5195^{**}	26.99% explained	

as predictors and the Word Recall Score as criterion.

Tables R7a and R8a are the correlation matrices and these show many similarities. The electrodermal measures inter-correlate. Figure Reversal Rate inter-correlates with both Basal Conductance level and Mean Conductance Change. Basal Conductance level both post-learning and post-recall correlates at the .05 level of confidence with Word Recall as does the E scale score. The N scale score is highly significantly correlated with the criterion. The major difference between the two matrices is the significant correlation of the criterion with Inspiration/Respiration Ratio measured post-recall, whereas the correlation between the criterion and the post-learning measure of the same variables is negligible.

Tables R7b and R8b show the regression equation coefficients and Multiple R's. The post-recall measures account for slightly more of the variance (45.7%) than the post-learning measures (40.9%). Corrected Multiple R's are significant beyond the .01 level of confidence.

The elimination procedure, Tables R7c and R8c, gives different results for the two sets of measurements. The N scale score (which was of course the same in both cases) proves by this method of analysis to be an efficient predictor in an equation significant at the .001 level of confidence. Basal Conductance level is retained in both cases to the 1% level. In the case of the post-learning measures Mean Conductance Change is retained to the 5% level. This variable measured post-recall

has a t-ratio which just falls short of significance. Inspiration/Respiration Ratio measured post-recall is retained to the 5% level of confidence. Table R8d shows the correlations of the post-learning and post-recall variables.

Table R8d

Variable	Pearson 'r'
Basal Conductance Level	.958**
Mean Conductance Change	.703**
Number of Galvanic Skin Responses	.683**
Respiration Rate	.806**
Mean Inspiration/Respiration Ratio	.506**

Fourth Multiple Correlation Analysis 'RESTING LEVELS/ REACTION TIME'

This analysis includes all the resting physiological variables measured during Session Two and Eyeblink Rate measured in Session One as predictors against the criterion of a 'reversed' score of the mean of the best ten reaction times.[1]

Table R9a is the correlation matrix. Mean Basal Conductance level correlates with the criterion and the criterion with

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[1] The score was reversed by subtracting each value from 300. Again this results in high scores being 'good'.

TABLE R9a Correlation Matrix 'RESTING LEVELS/REACTION TIME'

1	BC2	1					
2	No.GSR2	0.169	2				
3	MCC2	0.488**	0.178	3			
4	EMG1.2	-0.097	-0.096	-0.112	4		
5	EMG2.2	0.060	-0.043	0.006	0.589**	5	
6	EMG3.2	0.084	-0.039	0.074	0.496**	0.462**	6
7	HR2	0.245*	0.169	0.036	-0.106	-0.109	0.012
8	RR2	0.124	0.110	-0.060	0.009	-0.017	-0.060
9	I/R2	0.029	0.225	0.032	0.078	0.080	-0.023
10	EBR1	0.109	0.085	0.071	0.225	0.086	0.307*
11	Best 10 RT (Reversed)	0.267*	0.081	0.026	-0.166	-0.168	-0.173

TABLE R9a cont.

7	HR2	7				
8	RR2	0.335**	8			
9	I/R2	0.368**	0.121	9		
10	EBR1	0.025	0.063	-0.027	10	
11	Best 10 RT (Reversed)	-0.039	0.084	-0.127	-0.265*	11

TABLE R9b Regression Equation 'RESTING LEVELS/REACTION TIME'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
11	Best 10 RT (Reversed)				67	2.0870×10^{4}	3.1149×10^{2}
11	Best 10 RT (Reversed)				57	1.5763×10^{4}	2.7654×10^{2}
1	BC2	1.3434×10^{-3}	4.7411×10^{-4}	2.83			
2	No.GSR2	1.5850×10^{-1}	1.9543×10^{-1}	0.81			
3	MCC2	-4.5957×10^{-3}	4.4383×10^{-3}	1.04			
4	EMG1.2	1.1876×10^{-1}	3.8552×10^{-1}	0.31			
5	EMG2.2	-3.3973×10^{-1}	2.8931×10^{-1}	1.17			
6	EMG3.2	-8.0246×10^{-2}	3.0004×10^{-1}	0.27			
7	HR2	-2.1898×10^{-1}	2.1108×10^{-1}	1.04			
8	RR2	5.1998×10^{-1}	7.2109×10^{-1}	0.72			
9	I/R2	-3.9084×10^{-1}	4.5028×10^{-1}	0.87			
10	EBR1	-5.6299×10^{-1}	2.3636×10^{-1}	2.38			
CONSTANT		1.1394×10^{2}	1.9480×10				

F = 1.8468 P = 7.2718×10^{-2}

R = 0.4947* 24.47% explained

Corrected R = 0.3350

TABLE R9c Elimination 'RESTING LEVELS/REACTION TIME'

Variable	B	SE(B)	t	DF	Res SS	Res MS
10.0% Significance Level						
11 Best 10 RT (Reversed)				65	1.7548×10^{4}	2.6996×10^{2}
1 BC2	1.0143×10^{-3}	3.8722×10^{-4}	2.62			
10 EBR1	-5.6714×10^{-1}	2.1773×10^{-1}	2.60			
CONSTANT	8.7166×10	4.4823				
				F = 6.1535	P = 3.5693×10^{-3}	
				R = 0.3990**	15.92% explained	
				Corrected R = 0.3652**		
5.0% Significance Level	NO CHANGE					
1.0% Significance Level						
11 Best 10 RT (Reversed)				66	1.9379×10^{4}	2.9363×10^{2}
1 BC2	9.0456×10^{-4}	4.0144×10^{-4}	2.25			
CONSTANT	7.9293×10	3.4520				
				F = 5.0774	P = 2.7568×10^{-2}	
				R = 0.2673*	7.14% explained	

Eyeblink Rate gives a negative correlation both at the .05 level of confidence. Table R9b showing the regression equation coefficients also shows a non-corrected R which is significant only at the .05 level and a non-significant corrected R. The elimination, Table R9c, retains Basal Conductance and Eyeblink Rate to the 5% level and gives a corrected multiple R significant at the .01 level. Basal Conductance is the only variable retained when the equation is tested at the 1% level, after which the elimination terminates.

Fifth Multiple Correlation Analysis 'REACTION TIME'

The predictor variables here are those measured during the reaction time task or after the subject had been told of the task and was waiting for the first stimulus. The criterion was again the reversed mean of the Best 10 Reaction Times. The correlation matrix, Table R10a, shows again a correlation between Basal Conductance level and Mean Conductance Change. The EMG measures intercorrelated and Inspiration/Respiration Ratio correlates with Heart Rate at the .05 level of confidence. Mean Basal Conductance and GSR latency correlate with the criterion, in the latter case negatively. A most interesting finding is the correlation of mean GSR latency with Basal Conductance (.01 level), number of GSR's (.05 level), Mean Conductance Change (.01 level) and Heart Rate (.01 level), in all cases the correlations being negative. There is clearly no correlation between this variable and the EMG measures, but the negative correlation

TABLE R10a Correlation Matrix 'REACTION TIME'

1	BCRT	1					
2	No.GSRWL	-0.126	2				
3	MCCRT	0.319**	0.585**	3			
4	RRRT	0.159	-0.152	0.089	4		
5	I/RRT	-0.013	0.176	0.186	0.175	5	
6	HRRT	0.132	0.034	0.009	0.139	0.290*	6
7	EMG1RT	-0.035	-0.219	-0.201	0.024	0.210	-0.081
8	EMG2RT	0.141	-0.139	-0.057	0.145	0.141	-0.099
9	EMG3RT	0.071	-0.154	-0.084	0.136	0.143	-0.114
10	Mean latency	-0.520**	-0.290*	-0.440**	-0.212	-0.126	-0.403**
11	Best 10 RT (Reversed)	0.341**	-0.028	0.175	-0.031	-0.035	0.046

TABLE R10a cont.

7	EMG1RT	7				
8	EMG2RT	0.578**	8			
9	EMG3RT	0.584**	0.542**	9		
10	Mean latency	0.030	0.062	0.045	10	
11	Best 10 RT (Reversed)	0.001	-0.028	-0.089	-0.392**	11

TABLE R10b Regression Equation 'REACTION TIME'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
11	Best 10 RT (Reversed)				67	2.0870×10^{4}	3.1149×10^{2}
11	Best 10 RT (Reversed)				57	1.5826×10^{4}	2.7765×10^{2}
1	BCRT	4.5598×10^{-4}	7.1590×10^{-4}	0.64			
2	No.GSRWL	-3.2872×10^{-1}	2.5327×10^{-1}	1.30			
3	MCCRT	5.6017×10^{-3}	1.0310×10^{-2}	0.54			
4	RRRT	-7.6151×10^{-1}	6.4804×10^{-1}	1.18			
5	I/RRT	1.1443×10^{-2}	4.4393×10^{-1}	0.03			
6	HRRT	-1.7605×10^{-1}	1.8990×10^{-1}	0.93			
7	EMG1RT	1.3484×10^{-1}	4.4123×10^{-1}	0.31			
8	EMG2RT	1.5779×10^{-2}	2.4852×10^{-1}	0.06			
9	EMG3RT	-2.0661×10^{-1}	2.3419×10^{-1}	0.88			
10	Mean latency	-3.2832×10	1.3031×10	2.52			
	CONSTANT	2.0015×10^{2}	4.9620×10				

F = 1.8166 P = 7.8174×10^{-2}

R = 0.4916* 24.17% explained

Corrected R = 0.3297

TABLE R10c Elimination 'REACTION TIME'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
	10.0% Significance Level						
11	Best 10 RT (Reversed)				66	1.7660×10^{4}	2.6757×10^{2}
10	Mean latency	-2.9109×10	8.4038	3.46			
	CONSTANT	1.5552×10^{2}	2.0312×10				
					$F = 1.1998 \times 10$		$P = 9.4018 \times 10^{-4}$
					$R = 0.3922^{**}$		15.38% explained
					Corrected R = 0.3756		
	5.0% Significance Level	NO CHANGE					
	1.0% Significance Level	NO CHANGE					

with Respiration Rate falls not too far short of significance and the correlation with Inspiration/Respiration Ratio, though far from significant is again in the negative direction.

The regression coefficients are given in Table R10b which also shows a non-significant corrected R.

Elimination (Table R10c) retains mean GSR latency in the equation to the 1% significance level. Once again a low t-ratio eliminates Basal Conductance level though this correlates significantly with the criterion.

Sixth Multiple Correlation Analysis 'RESTING LEVELS/TRACKING'

This analysis includes the resting physiological variables measured in Session Three, the respiration measures taken during rest in Session One, and N scale score, as predictors. In this case the criterion was time on target during pursuit rotor tracking.

The correlation matrix (Table R11a) shows no correlation between Basal Conductance level and the criterion. Variables which do correlate with the criterion, all negatively and at the .05 level of confidence, are EMG3, mean Eyeblink Rate and N scale score. Table R11b shows the regression equation coefficients. The corrected R is not significant.

Elimination (Table R11c) retains N scale score and EMG3 in the regression equations down to the 1% level. The corrected multiple R is significant at the .01 level. N scale score appears as the only predictor variable in an equation

TABLE R11a Correlation Matrix 'RESTING LEVELS/TRACKING'

		1	2	3	4	5	6
1	BC3						
2	No.GSR3	0.267*					
3	MCC3	0.643	0.371**				
4	EMG1.3	-0.160	0.184	0.015			
5	EMG2.3	-0.171	0.153	-0.057	0.517**		
6	EMG3.3	-0.071	0.058	0.082	0.561**	0.437**	
7	HR3	0.303**	0.107	0.135	-0.102	-0.291*	-0.075
8	RR1	0.157	0.093	0.083	-0.082	0.007	-0.048
9	I/R1	-0.041	0.133	-0.045	0.086	0.205	0.046
10	EBR3	-0.026	0.024	-0.091	-0.064	-0.071	0.014
11	N Score	-0.140	0.019	-0.076	0.017	0.011	-0.235
12	Tracking Score	0.067	-0.146	-0.022	-0.162	-0.189	-0.277*

TABLE R11a cont.

7	HR3	7					
8	RR1	0.192	8				
9	I/R1	0.171	0.007	9			
10	EBR3	0.046	0.147	0.028	10		
11	N Score	-0.060	0.180	0.090	0.158	11	
12	Tracking Score	0.129	-0.182	0.059	-0.256*	-0.281*	12

TABLE R11b Regression Equation 'RESTING LEVELS/TRACKING'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
12	Tracking Score				67	2.7130×10^{5}	4.0492×10^{3}
12	Tracking Score				56	1.9049×10^{5}	3.4017×10^{3}
1	BC3	5.7819×10^{-4}	3.0031×10^{-3}	0.19			
2	No.GSR3	-8.3869×10^{-1}	7.3727×10^{-1}	1.14			
3	MCC3	-1.0374×10^{-4}	3.2475×10^{-2}	0.00			
4	EMG1.3	8.4530×10^{-1}	1.5189	0.56			
5	EMG2.3	-4.1536×10^{-1}	1.2214	0.34			
6	EMG3.3	-2.1716	8.7844×10^{-1}	2.47			
7	HR3	5.9000×10^{-1}	8.1156×10^{-1}	0.73			
8	RR1	-2.4667	2.4907	0.99			
9	I/R1	1.7272	1.7673	0.98			
10	EBR3	-1.1630	7.3094×10^{-1}	1.59			
11	N Score	-5.0720	1.9878	2.55			
CONSTANT		1.1471×10^{2}	8.5555x10				

F = 2.1595 P = 3.0225×10^{-2}

R = 0.5458 * 29.78% explained

Corrected R = 0.400

TABLE R11c Elimination 'RESTING LEVELS/TRACKING'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
	10.0% Significance Level						
12	Tracking Score				65	2.1600×10^{5}	3.3232×10^{3}
6	EMG3.3	-2.1463	6.7304×10^{-1}	3.19			
11	N Score	-5.8866	1.8274	3.22			
	CONSTANT	1.7103×10^{2}	2.3548×10				
					F = 8.3194	P = 6.0678×10^{-4}	
					R = 0.4515**	20.38% explained	
					Corrected R = 0.424**		
	5.0% Significance Level	NO CHANGE					
	1.0% Significance Level	NO CHANGE					
	0.1% Significance Level						
12	Tracking Score				66	2.4980×10^{5}	3.7849×10^{3}
11	N Score	-4.5178	1.8957	2.38			
	CONSTANT	1.2470×10^{2}	1.9777×10				
					F = 5.6797	P = 2.0049×10^{-2}	
					R = 0.2815*	7.92% explained	

significant at the 0.1% level.

Seventh Multiple Correlation Analysis 'TRACKING'

This analysis includes Basal Conductance and EMG levels measured during tracking, Heart Rate measured after the subject had been told of the task and was waiting for the 'begin' instruction, and N scale score.

Table R12a shows the correlation matrix. The EMG measures intercorrelate as before and EMG2 correlates negatively with Heart Rate (.01 level) and Basal Conductance (.01 level). Heart Rate also correlates negatively with EMG1 (.05 level) but its correlation with Basal Conductance level just falls short of significance at the .05 level. Basal Conductance level is not significantly correlated with the criterion though this figure is appreciably higher than the comparable resting level correlation. N scale score correlates negatively with the criterion as seen in Table 11a. All the EMG scores correlate non-significantly and negatively with the criterion though in no case is the gap between the obtained result and the figure required for significance at the .05 level a large one.

Table R12b which shows the regression equation coefficients also shows a non-significant R.

The elimination (Table R12c), as in the previous analysis, (Table R11c), retains the N scale score.

TABLE R12a Correlation Matrix 'TRACKING'

1 BCT	1						
2 HR(T)	0.230	2					
3 EMG1(T)	-0.208	-0.253*	3				
4 EMG2(T)	-0.275*	-0.401**	0.611**	4			
5 EMG3(T)	-0.077	-0.049	0.475**	0.279*	5		
6 N Score	-0.136	-0.128	0.088	0.020	-0.036	6	
7 Tracking Score	0.181	0.101	-0.205	-0.236	-0.234	-0.281*	7

TABLE R12b Regression Equation 'TRACKING'

	Variable	B	SE(B)	t	DF	Res SS	Res MS
7	Tracking Score				67	2.7130×10^{5}	4.0492×10^{3}
7	Tracking Score				61	2.2358×10^{5}	3.6652×10^{3}
1	BCT	1.6046×10^{-3}	2.1634×10^{-3}	0.74			
2	HR(T)	-1.6022×10^{-1}	6.8521×10^{-1}	0.23			
3	EMG1(T)	3.1781×10^{-1}	1.1804	0.27			
4	EMG2(T)	-1.1236	9.4800×10^{-1}	1.19			
5	EMG3(T)	-1.0707	6.8818×10^{-1}	1.56			
6	N Score	-4.5012	1.9092	2.36			
	CONSTANT	1.6414×10^{2}	6.7532x10				

F = 2.1700 P = 5.8117×10^{-2}

R = 0.4194 17.59% explained

Corrected R = 0.3080

TABLE R12c Elimination 'TRACKING'

Variable	B	SE(B)	t	DF	Res SS	Res MS
10.0% Significance Level						
7 Tracking Score				66	2.4980×10^{5}	3.7849×10^{3}
6 N Score	-4.5178	1.8957	2.38			
CONSTANT	1.2470×10^{2}	1.9777x10				
				F = 5.6797	P = 2.0049×10^{-2}	
				R = 0.2815*	7.92% explained	
5.0% Significance Level	NO CHANGE					

Summary of Inter-relationships

Figure 8, page 195, is an attempt to summarise the correlations found in the present study.

Every variable used in the study can be seen to be related to at least one other variable. Basal Skin Conductance appears in the most correlations (partly because this variable was recorded on more occasions), and correlates with three of the four performance measures. All the electrodermal measures intercorrelate. Heart Rate and GSR latency appear to be variables which have possibilities in this field of study. N scale score seems to be associated with learning ability at any rate in the tasks used here, tasks which required fairly prolonged concentration. The three EMG measures intercorrelate strongly and there is slight evidence of a relationship between these measures and Eyeblink Rate. On the evidence of the present data, Respiration Rate seems to be the least useful measure. This measure is not related to Inspiration/Respiration Ratio, a measure which may prove to be more useful as an index of performance. Figure Reversal Rate seems to be a possible index and is certainly, on the present evidence, very reliable. Its correlation with Threshold score might have been predicted. This performance measure does not correlate with any of the other performance tasks used. It is of course the most passive of the four tasks used, requiring close attention but little effort. The Reaction Time, Tracking and Word Recall tasks are related. They are altogether more active tasks, though they too demand close attention.

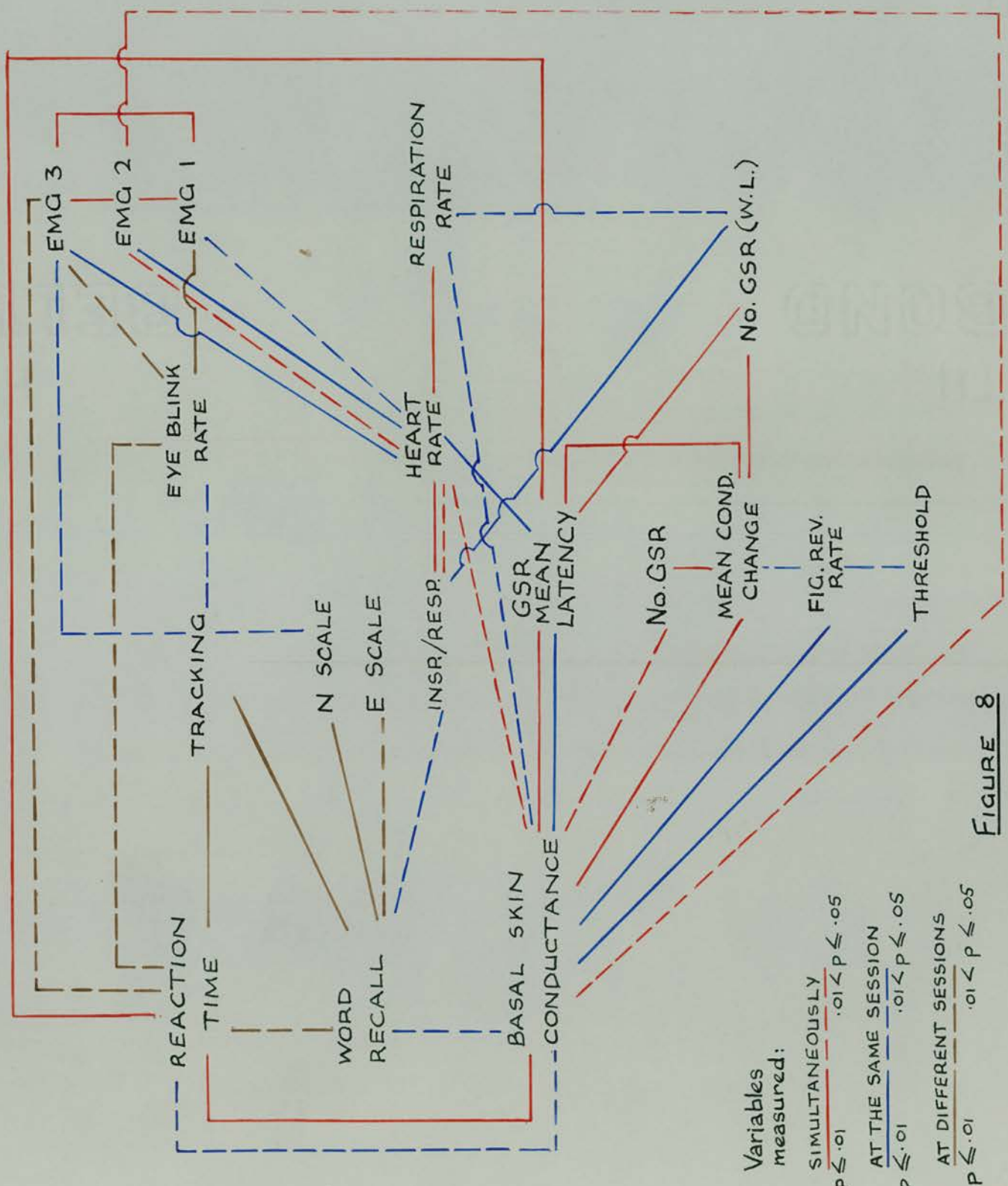
EMG 3
EMG 2
EMG 1
EYE BLINK RATE
RESPIRATION RATE
HEART RATE
No. GSR (W.L.)
TRACKING
N SCALE
E SCALE
INSR/RESP.
GSR MEAN LATENCY
No. GSR
MEAN COND. CHANGE
FIG. REV. RATE
THRESHOLD
REACTION TIME
WORD RECALL
BASAL SKIN CONDUCTANCE
Variables measured:
SIMULTANEOUSLY
p ≤ .01 .01 < p ≤ .05
AT THE SAME SESSION
p ≤ .01 .01 < p ≤ .05
AT DIFFERENT SESSIONS
p ≤ .01 .01 < p ≤ .05

FIGURE 8

Table R13 lists the correlations summarised in Figure 8.

TABLE R13 (and see Figure 8)

Summary of significant correlations

VARIABLES	WHEN MEASURED	PEARSON r
BC2 / Best 10 RT (Reversed)	Session Two	0.267*
BCRT / Best 10 RT (Reversed)	Session Two	0.341**
BC1 / Reversed Threshold Score	Session One	0.440**
BC1 / Recall Score	Session One	0.262**
BC1 / $FRR1_1$	Session One	0.346*
BC1 / MCC1	Session One	0.439**
No.GSR1 / MCC1	Session One	0.413**
$FRR1_1$ / Reversed Threshold Score	Session One	0.240*
BCPL / No.GSRPL	Session One	0.263*
BCPL / MCCPL	Session One	0.453**
No.GSRPL / MCCPL	Session One	0.414**
BCPL / $FRR1_1$	Session One	0.384**
BCPL / Recall Score	Session One	0.257*
MCCPL / $FRR1_1$	Session One	0.240*
N Score / Recall Score	Session Three/One	-0.520**
E Score / Recall Score	Session Three/One	-0.293*
BCPRcl / No.GSRPRcl	Session One	0.246*
BCPRcl / MCCPRcl	Session One	0.593**
No.GSR / MCCPRcl	Session One	0.328**

TABLE R13 cont.

VARIABLES	WHEN MEASURED	PEARSON r
BCPRcl / $FRR1_2$	Session One	0.413**
BCPRcl / Recall Score	Session One	0.256*
MCCPRcl / $FRR1_2$	Session One	0.248*
I/RPRcl / Recall Score	Session One	-0.273*
BCRT / MCCRT	Session Two	0.319**
BCRT / Mean latency	Session Two	-0.520**
No.GSRWL / MCCRT	Session Two	0.585**
No.GSRWL / Mean latency	Session Two	-0.290*
MCCRT / Mean latency	Session Two	-0.440**
I/RRT / HRRT	Session Two	0.290*
HRRT / Mean latency	Session Two	-0.403**
BCRT / Best 10 RT (Reversed)	Session Two	0.341**
EMG1RT / EMG2RT	Session Two	0.578**
EMG1RT / EMG3RT	Session Two	0.584**
EMG2RT / EMG3RT	Session Two	0.542**
Best 10 RT (Reversed) / Mean latency	Session Two	-0.392**
Best 10 RT (Reversed) / EBR1	Session Two/One	-0.265*
BC2 / MCC2	Session Two	0.488**
BC2 / HR2	Session Two	0.245*
EMG1.2 / EMG2.2	Session Two	0.589**
EMG2.2 / EMG3.2	Session Two	0.462**
EMG1.2 / EMG3.2	Session Two	0.496**
EMG3.2 / EBR1	Session Two/One	0.307*

TABLE R13 cont.

VARIABLES	WHEN MEASURED	PEARSON r
HR2 / RR2	Session Two	0.335**
HR2 / I/R2	Session Two	0.368**
No.GSRWL / I/R2	Session Two	0.329**
BCRT / RR2	Session Two	0.249*
BC2 / Mean latency	Session Two	-0.371**
BCT / EMG2(T)	Session Three	-0.275*
HR(T) / EMG1(T)	Session Three	-0.253*
HR(T) / EMG2(T)	Session Three	-0.401**
EMG1(T) / EMG2(T)	Session Three	0.611**
EMG2(T) / EMG3(T)	Session Three	0.279*
EMG1(T) / EMG3(T)	Session Three	0.475**
BC3 / No.GSR3	Session Three	0.267*
BC3 / MCC3	Session Three	0.643**
No.GSR3 / MCC3	Session Three	0.371**
BC3 / HR3	Session Three	0.303*
EMG2.3 / HR3	Session Three	-0.291*
EMG1.3 / EMG2.3	Session Three	0.517**
EMG2.3 / EMG3.3	Session Three	0.437**
EMG1.3 / EMG3.3	Session Three	0.561**
Best 10 RT (Reversed) / EMG 3.3	Session Two/Three	-0.301*
Tracking Score / Best 10 RT (Reversed)	Session Three/Two	0.592**
Best 10 RT (Reversed) / Recall Score	Session Two/One	0.287*
Tracking Score/ Recall Score	Session Three/One	0.378**

TABLE R13 cont.

VARIABLES	WHEN MEASURED	PEARSON r
Tracking Score / N Score	Session Three	-0.281*
Tracking Score / EMG3.3	Session Three	-0.277*
Threshold Score / Overall FRR	Session One/One & Three	-0.318**
Reversed Threshold Score / MCC3	Session One /Three	0.281*
Tracking Score / EBR3	Session Three	-0.256*
BCRT / BC2	Session Two	0.841**
BCRT / MCC2	Session Two	0.335**
BCRT / HR2	Session Two	0.316**
MCCRT / No.GSR2	Session Two	0.255*
RRRT /HR2	Session Two	0.327**
RRRT / RR2	Session Two	0.650**
I/RRT / I/R2	Session Two	0.486**
HRRT / HR2	Session Two	0.664**
HRRT/ I/R2	Session Two	0.403**
EMG1RT / EMG1.2	Session Two	0.740**
EMG1RT / EMG2.2	Session Two	0.565**
EMG1RT / EMG3.2	Session Two	0.480**
EMG1RT / EBR1	Session Two/One	0.253*
EMG2RT / EMG1.2	Session Two	0.496**
EMG2RT / EMG2.2	Session Two	0.768**
EMG2RT / EMG3.2	Session Two	0.483**

TABLE R13 cont.

VARIABLES	WHEN MEASURED	PEARSON r
EMG3RT / EMG1.2	Session Two	0.412**
EMG3RT / EMG2.2	Session Two	0.403**
EMG3RT / EMG3.2	Session Two	0.748**
Mean latency / HR2	Session Two	-0.253*
Mean latency / RR2	Session Two	-0.278*

Autonomic Lability Scores

The Lacey Autonomic Lability Score (ALS) described in Chapter III was examined. The scores were calculated for Basal Conductance level and Heart Rate for Session Two and Session Three. In the computation of these scores the 'pre-stimulus' standard scores were calculated from the resting measures taken during the first five minutes of the sessions. The 'post-stimulus' standard scores were calculated from the within-task recording in the case of Skin Conductance and in the case of Heart Rate from the scores recorded during the twenty second period immediately following the subject being told of the task and while he was, as it were, 'poised' to begin. The calculated scores are shown in Table D9, Appendix 1.

Table R14 shows the correlations between the obtained autonomic lability scores, and Table R15 shows ALS and two performance score correlations.

On these results the Lacey scores do not improve upon the raw measures employed here. The autonomic lability scores derived from Skin Conductance seem to be more reliable and, in terms of correlation with performance criteria, more valid than those derived from Heart Rate.

Relationships between resting and performance measures

The correlations between resting and performance measures were calculated and these are shown in Table R16. Examination of the Data Tables (Appendix 1) shows that there is a good deal of individual variation in the change in autonomic activity from resting to active conditions. For example, in the case of resting heart rate, comparing rates measured during the

TABLE R14

	Pearson r
Conductance ALS Reaction Time and Tracking	0.376**
Heart Rate ALS Reaction Time and Tracking	0.252*
Reaction Time Conductance ALS and Heart Rate ALS	-0.021
Tracking Conductance ALS and Heart Rate ALS	-0.172

TABLE R15

	Pearson r
Best 10 RT and Conductance ALS (RT)	-0.216
Best 10 RT and Heart Rate ALS (RT)	-0.097
Tracking score and Conductance ALS (T)	0.220
Tracking score and Heart Rate ALS (T)	-0.017

first five minutes of Session Three and those measured during the twenty seconds following the subject being told of the tracking task, twenty-four subjects show a fall in Heart Rate, seven show no change (or a change of less than one beat per minute) and thirty-seven subjects show a rise. A similar comparison of the same variable in Session Two and the reaction time task gives seven subjects showing a fall, five showing no change and fifty-six showing a rise in Heart Rate. The marked tendency in all cases is for all variables to show a significant rise.

TABLE R16

Variables	Correlated t	Pearson r
RR2 and RRRT	6.358**	0.650**
I/R2 and I/RRT	2.399*	0.486**
HR2 and HRRT	7.368**	0.665**
BC2 and BCRT	3.624**	0.841**
EMG1.2 and EMG1RT	2.236*	0.740**
EMG2.2 and EMG2RT	2.143*	0.767**
EMG3.2 and EMG3RT	4.339**	0.748**
HR3 and HR(T)	2.891**	0.838**
BC3 and BCT	5.742**	0.799**
EMG1.3 and EMG1(T)	3.421**	0.708**
EMG2.3 and EMG2(T)	4.858**	0.690**
EMG3.3 and EMG3(T)	5.255**	0.756**

Table R16 shows a series of correlated t ratios and corresponding

correlation coefficients for variables measured during rest and during activity.

Intra-individual Analyses

In view of the fact that previous studies have examined intra-individual differences and of the present finding of differences in the direction of change between rest and activity between some of the subjects, it was decided to examine Basal Conductance level and Mean Conductance Change for a selection of the sample during the reaction time task. Both autonomic variables were continuously monitored during the task and the spread of reaction times over the fifty trials gives a changing performance score for the same period. Twenty subjects were chosen from the sample for examination. These were the top and bottom ten ranked subjects in terms of the mean of the best ten reaction times. For these subjects mean 'reversed' reaction times (obtained by subtracting the recorded reaction time from 500 msec.) were calculated for blocks of ten trials (trial numbers 1 to 10, 11 to 20, 21 to 30, 31 to 40 and 41 to 50). Mean Basal Conductance and Mean Conductance Change for the time periods occupied by each of these blocks of trials was also calculated. These results are shown in Table D10, Appendix 1. Graphs were drawn of Reversed RT against Basal Conductance level and against Mean Conductance Change and these are shown on pages 209 to 221. (The numbers in the top right-hand corner of each graph are the subject identification numbers.) It might be expected from the results of previous research that these graphs would yield

inverted U-shaped curves. Examination of the graphs showing Reversed RT against Mean Conductance Change shows that eight of the twenty graphs are 'inverted U's', nine have a downward linear trend (deteriorating performance with increasing Mean Conductance Change) and three have an upward linear trend (improved performance with increasing Mean Conductance Change). Reversed RT against Basal Conductance level gives thirteen 'inverted U's', three downward linear trends, one upward linear trend, two U-shaped plots (!) and one rather indeterminate configuration.[1] Is this evidence for the inverted U curve of activation? If the activation index changes as the task progresses in either a regularly increasing or decreasing way then 'intermediate' or 'moderate' levels for the individual will be seen in the middle of the task. If at the same time the best performance is found in the middle of the period and the worst at the beginning and end - a state of affairs which can be 'explained' in terms of 'warm-up' and 'fatigue' - then inevitably, the inverted U curve is generated, and better performance is associated with intermediate values of the index. The distribution of the best and worst ten reaction times for all sixty-eight subjects was examined. The series was divided for convenience into successive 5 - block trials and a count taken of the occurrence of the best and worst ten reaction times in each successive block. The graphs on

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[1] The shape of the curves drawn in on the plots was determined by inspection. They are not necessarily the 'best fit' curves mathematically.

pages 222 to 223 show these frequency distributions and it can be seen that it is during the second, third and fourth trial blocks that the best performances occur and the likelihood of the generation of the inverted U curve is established.[1] The improvement in performance in the last block of trials might be accounted for as an 'end-spurt'. (Although the subjects were not told the precise number of trials in the reaction time task, they did know that they could earn "over twelve shillings", and a very straightforward computation would have given them a close approximation to the length of the series).

For the same twenty subjects (top and bottom ten ranked subjects in terms of the mean of the best ten reaction times), intra-individual and inter-individual differences in foreperiod times, GSR latencies to the associated warning light stimuli and mean conductance changes for the best and worst ten reaction times were examined. Table R17 shows the results of a series of t tests. Only one of the differences proved to be significant and that did not reach the .01 level of confidence. An interesting point is that GSR latency does not discriminate between different levels of performance within subjects nor between subjects, when means of either the latencies associated with the warning lights accompanying the best ten or the worst ten reaction times are considered. Overall mean GSR latency does however discriminate

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[1] These distributions are skewed partly because in the case of ties for tenth rank, the reaction time nearest the beginning of the series was chosen.

rather effectively between subjects as we have seen. This index thus appears to be a more general measure of level of performance or efficiency for a particular individual than a fine discriminator of 'ripples' in performance within the individual.

TABLE R17

Difference between means of:	Top ten subjects Correlated t	Bottom ten subjects. Correlated t
Best ten RT foreperiods and Worst ten RT foreperiods	1.423	0.618
Best ten RT GSR latencies and Worst ten RT GSR latencies	0.336	1.503
Best ten conductance changes and Worst ten conductance changes	1.190	1.450

Difference between means for top ten and bottom ten subjects:	Uncorrelated t
Best ten RT foreperiods	0.667
Worst ten RT foreperiods	0.075
Best ten GSR latencies	1.785
Worst ten RT GSR latencies	0.813
Best ten RT conductance changes	2.254*
Worst ten RT conductance changes	1.071

SUMMARY OF THE MAIN FINDINGS

Principal Components analysis of the performance variables shows two important factors; 'perceptual-motor skill' associated with N scale score (best ten reaction time means,

Tracking score and Word Recall all intercorrelating) and a perceptual factor associated with 'cortical inhibition' (Threshold score, E score and Figure Reversal Rate).

Two factor analyses of the physiological variables show reasonable but by no means exact correspondence. A muscle tension factor is apparent and there is some evidence for a general autonomic factor. There is evidence for relationships between electrodermal, heart rate and respiration measures.

The multiple correlation analyses and elimination procedure carried out show the overwhelming superiority of Basal level of Skin Conductance as a predictor of performance on the Threshold, Word Recall and Reaction Time tasks. The physiological and personality variables accounted for relatively more of the variance in the 'passive' (Threshold and Word Recall) than in the 'active' (Reaction Time and Tracking) tasks. N score appears to be a moderately good predictor in the tasks which involve learning. Although Basal Conductance and N score show the best survival in the elimination procedures it was found that the full battery of predictor variables on average accounted for almost fifteen percent more of the variance than these final variables alone.

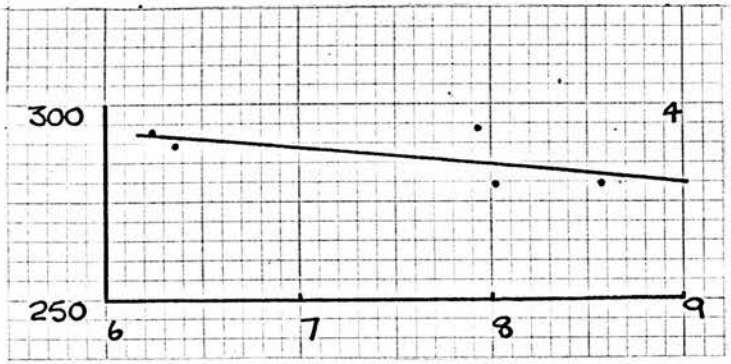
GSR latency not only appears as a relatively good predictor of reaction time performance but shows moderate relationships with other physiological measures used.

The 'autonomic lability scores' were not found to be

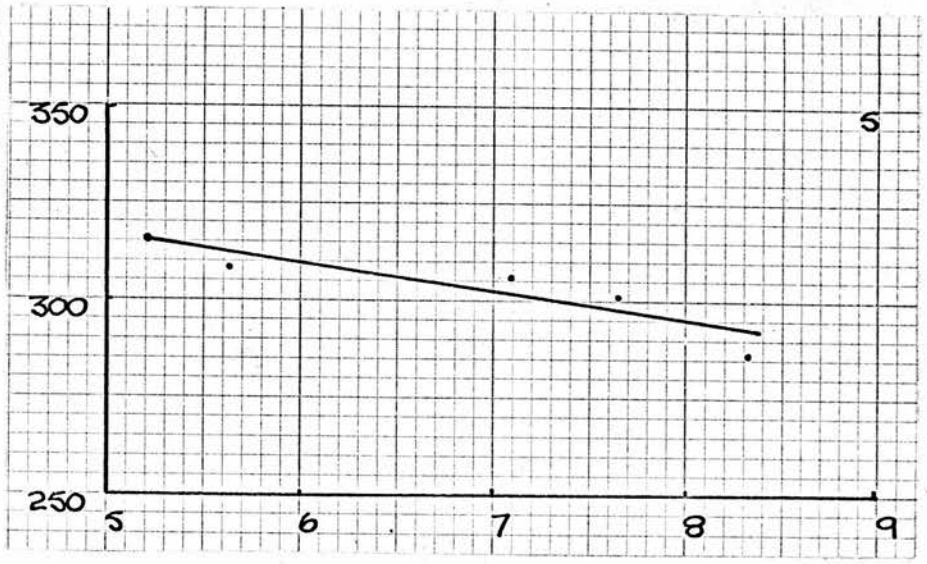
superior to other measures employed.

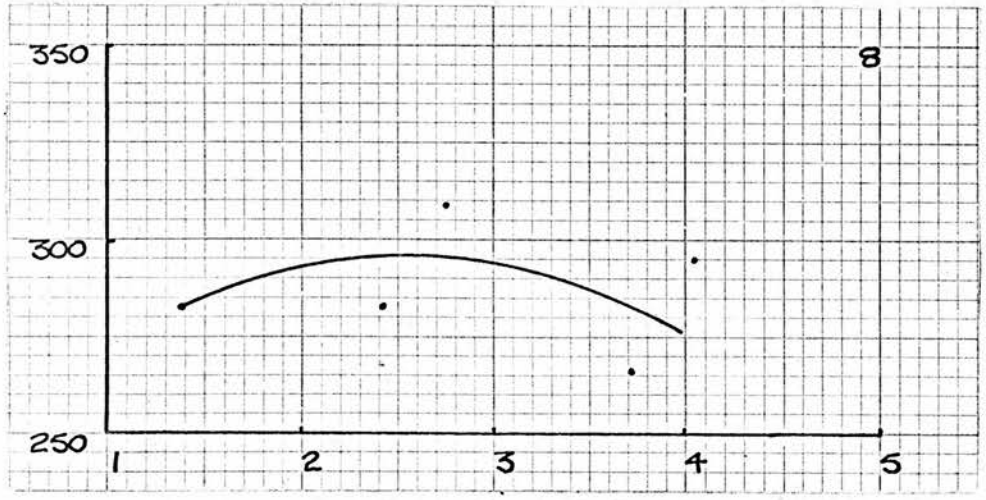
The marked tendency was for all the physiological variables to show an increased value during performance or preparation for performance as compared with rest. This rise was significant for all the variables. Correlation between resting and active measures was moderate to high.

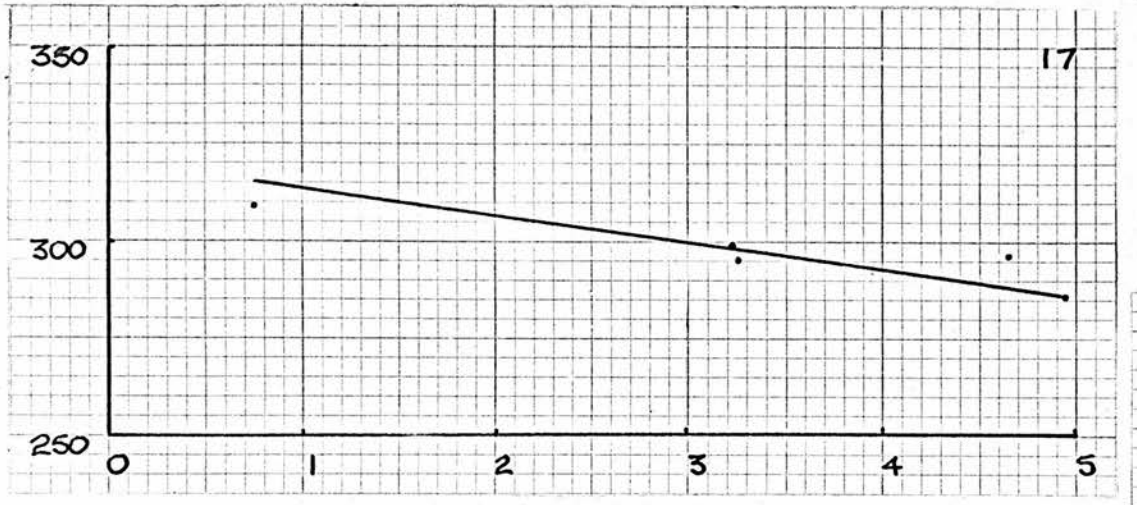
Some evidence of an inverted U relationship between reaction time performance and basal conductance level and mean conductance change was found in intra-individual analyses, though the suggestion is that these findings are not necessarily to be interpreted within the activation concept of the inverted U curve.

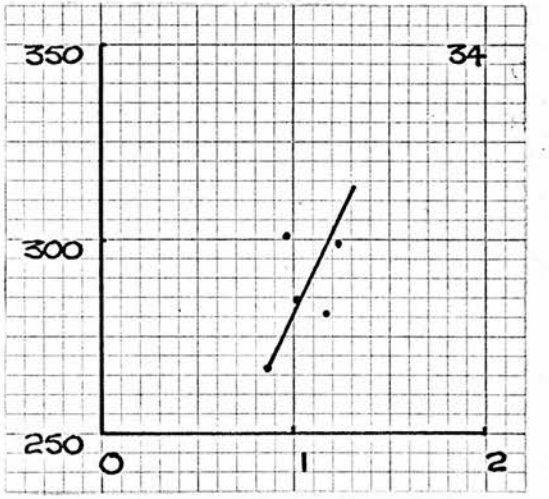


Mean 'reversed' reaction times (blocks of 10 trials) v. Mean conductance changes (blocks of 10 trials)

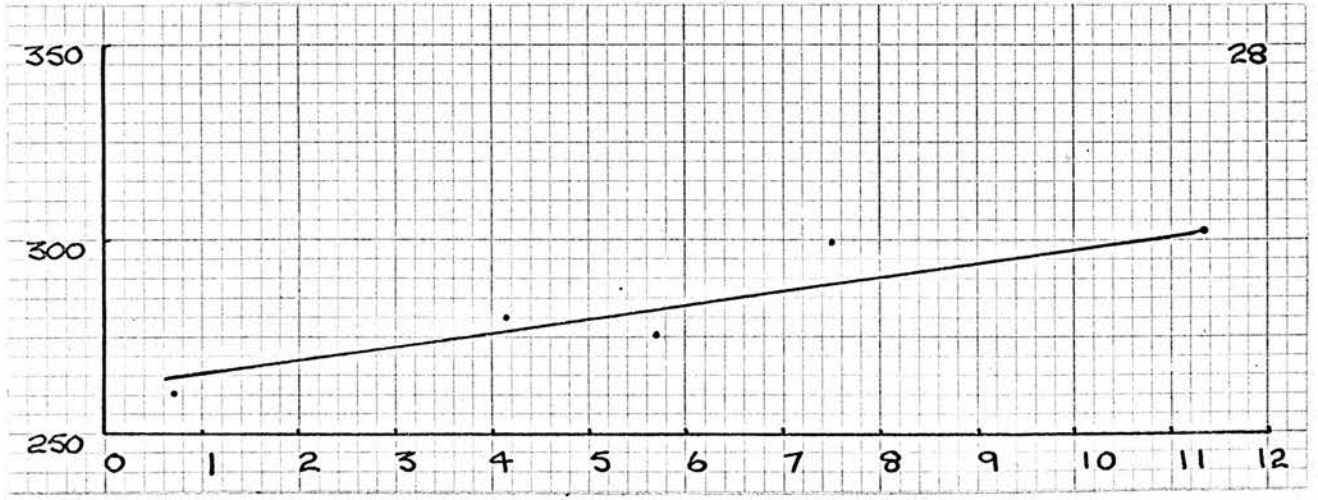




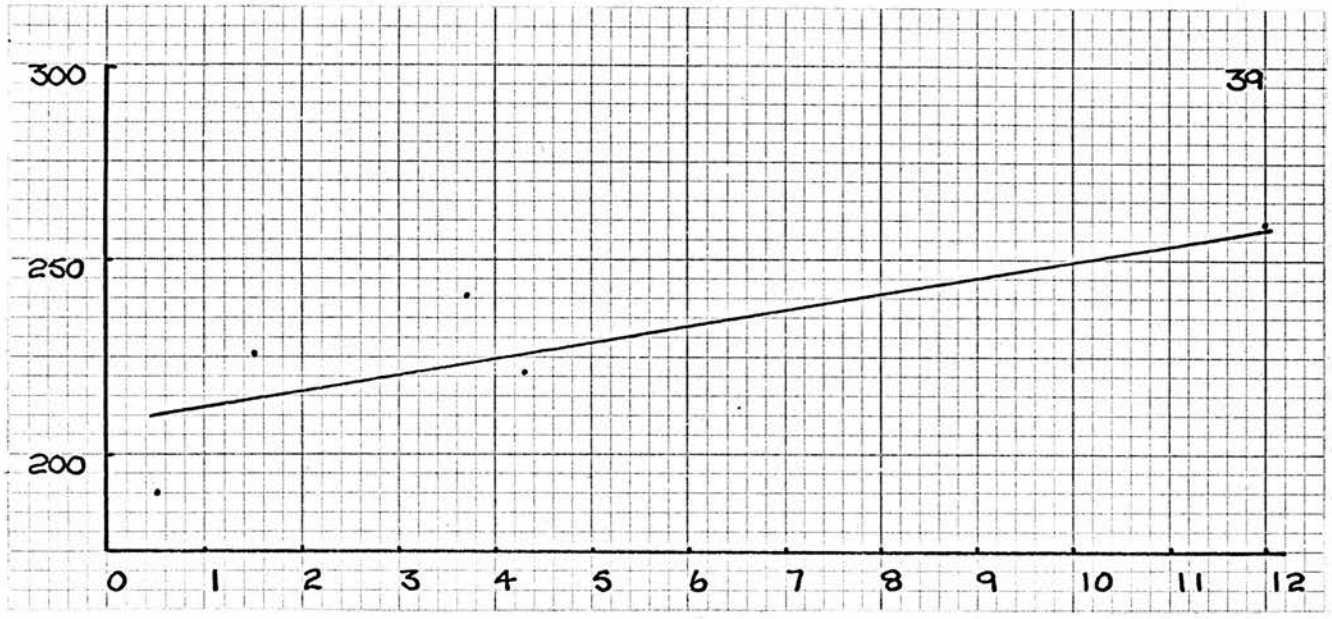


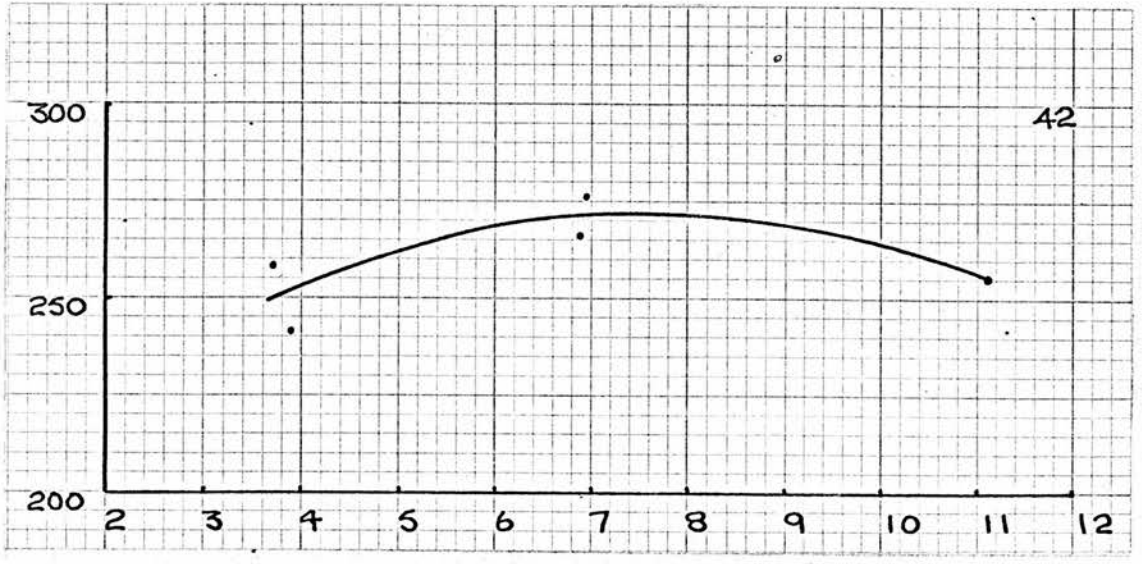


Mean 'reversed' reaction times (blocks of 10 trials) v. Mean conductance changes (blocks of 10 trials)

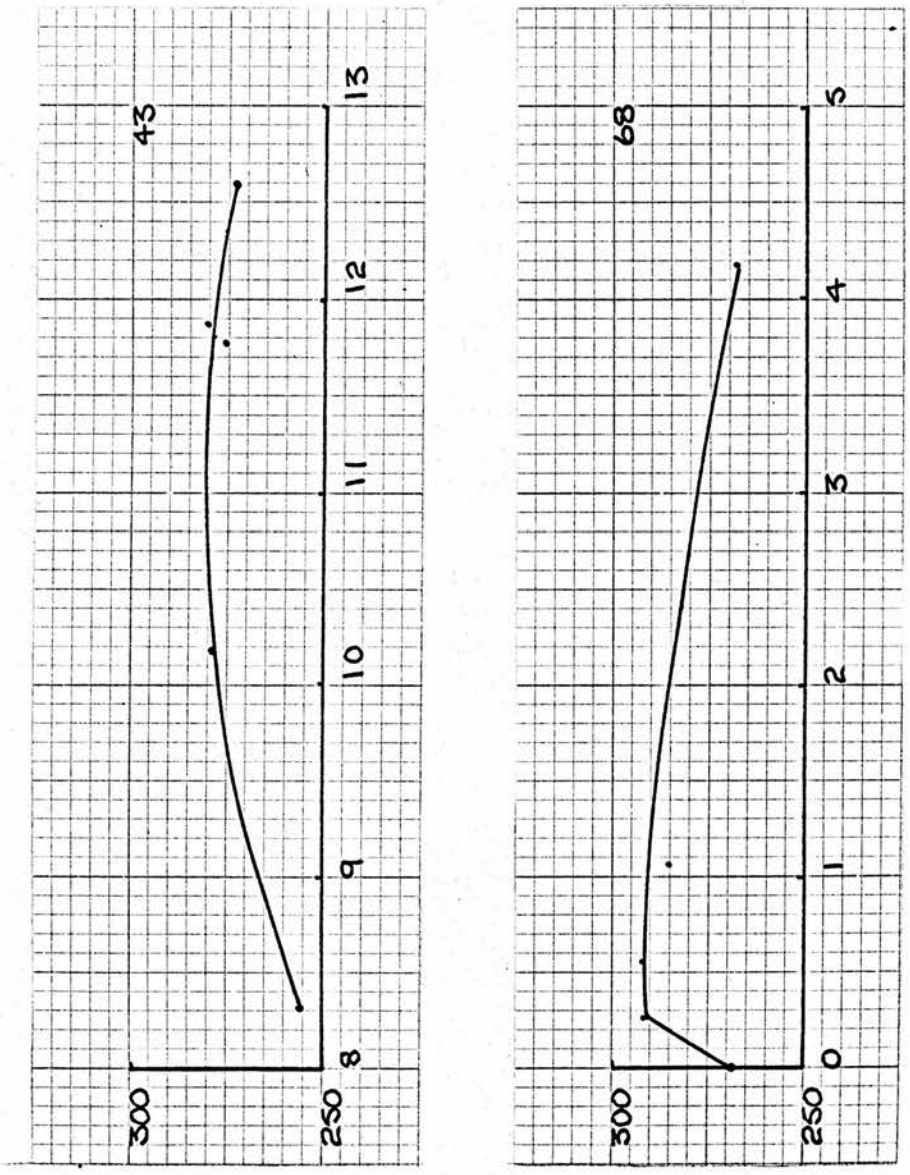


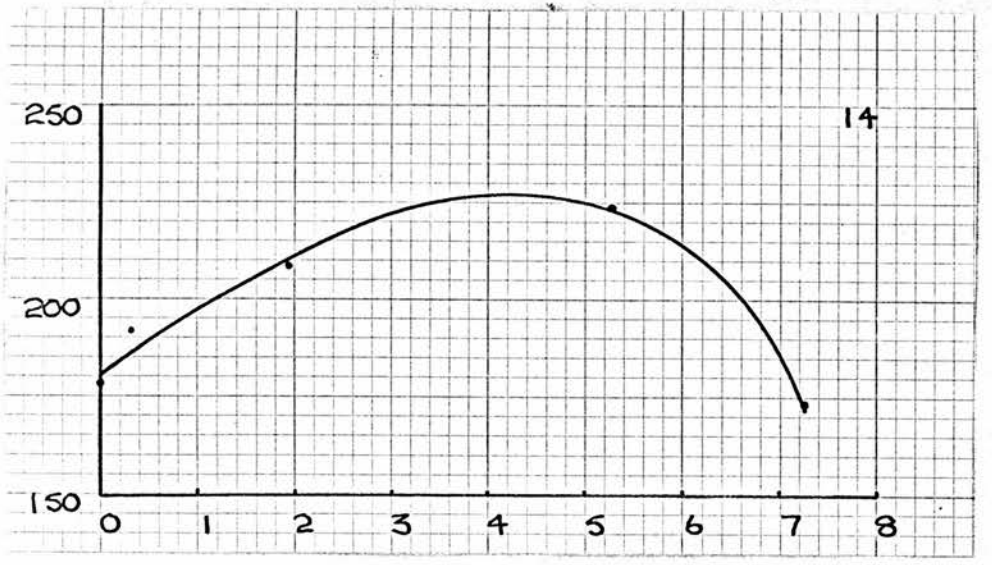
Mean 'reversed' reaction time (blocks of 10 trials) v. Mean conductance changes (blocks of 10 trials)



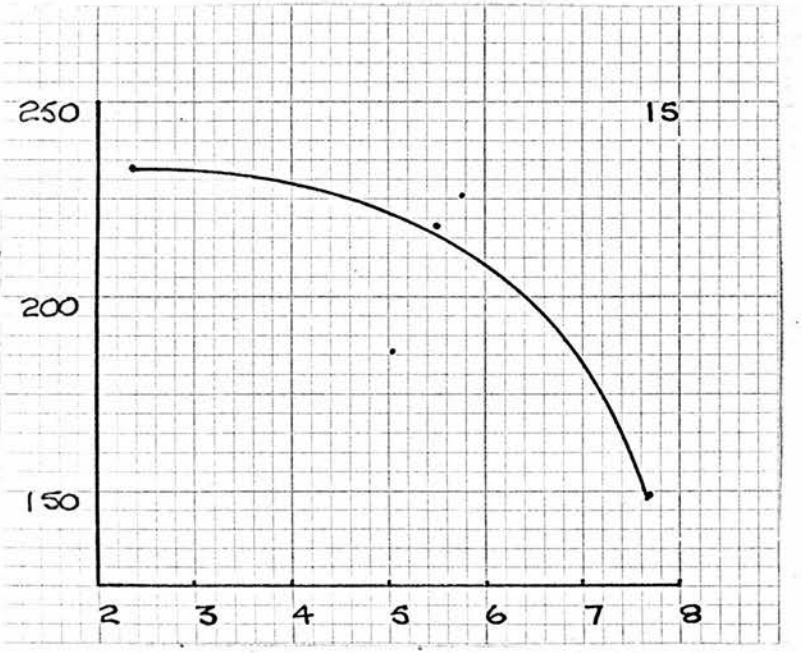


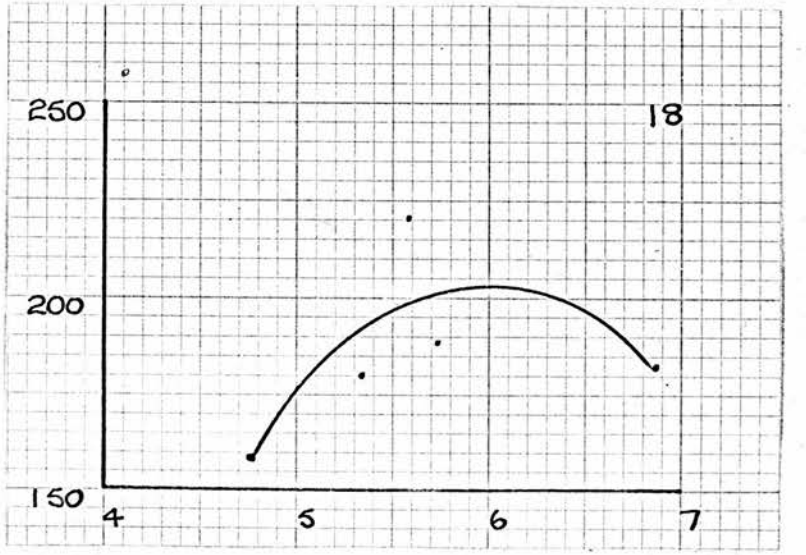
Mean 'reversed' reaction times (blocks of 10 trials) v. Mean conductance changes (blocks of 10 trials)

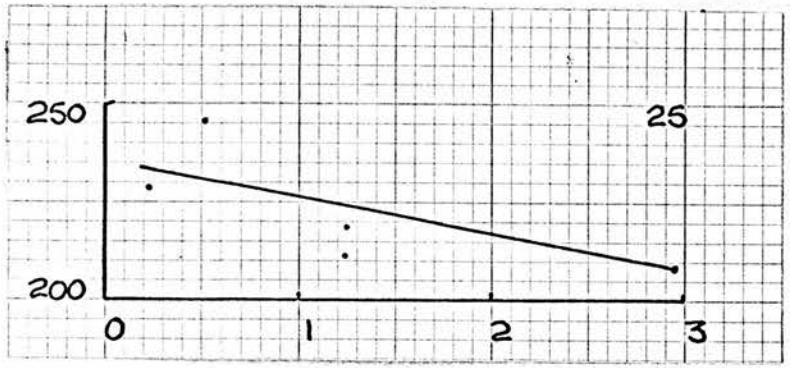




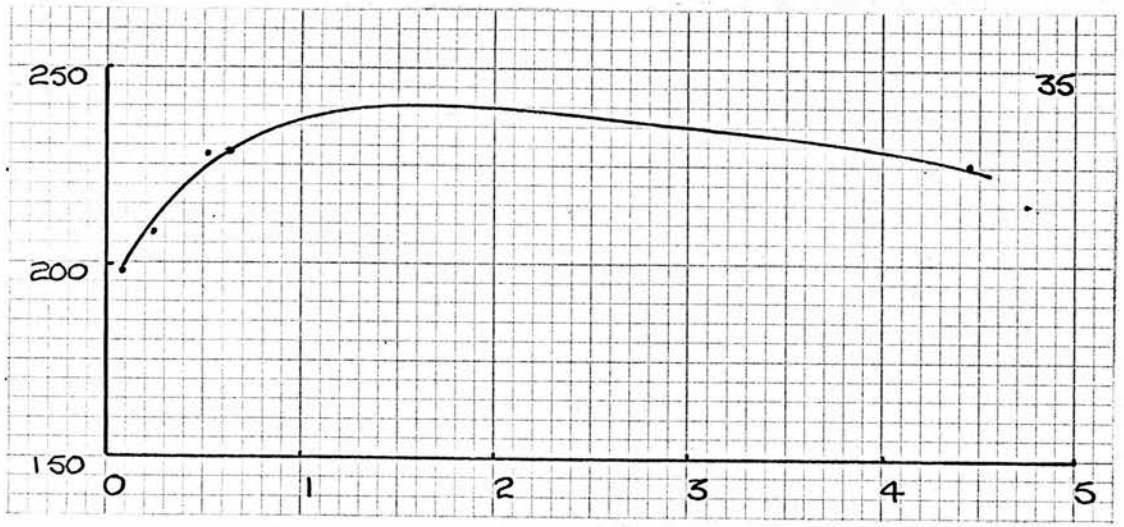
Mean 'reversed' reaction times (blocks of 10 trials) v. Mean conductance changes (blocks of 10 trials)

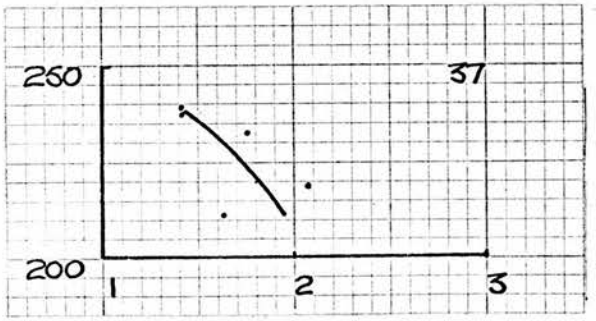




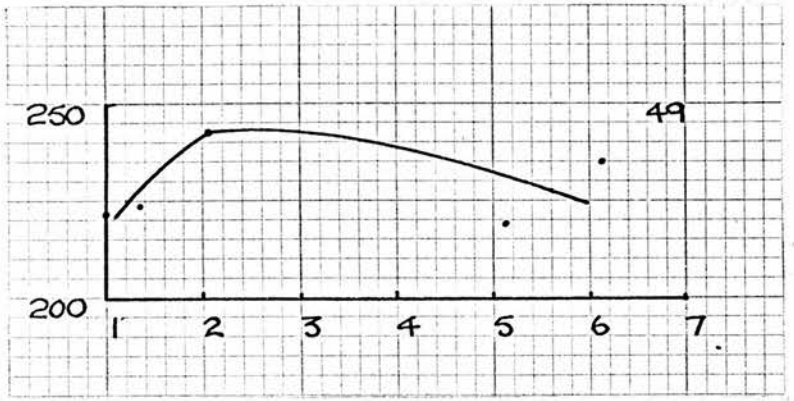


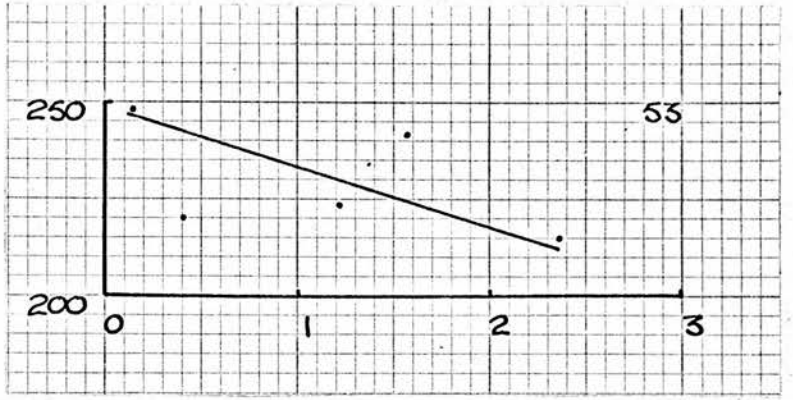
Mean 'reversed' reaction times (blocks of 10 trials) v. Mean conductance changes (blocks of 10 trials)

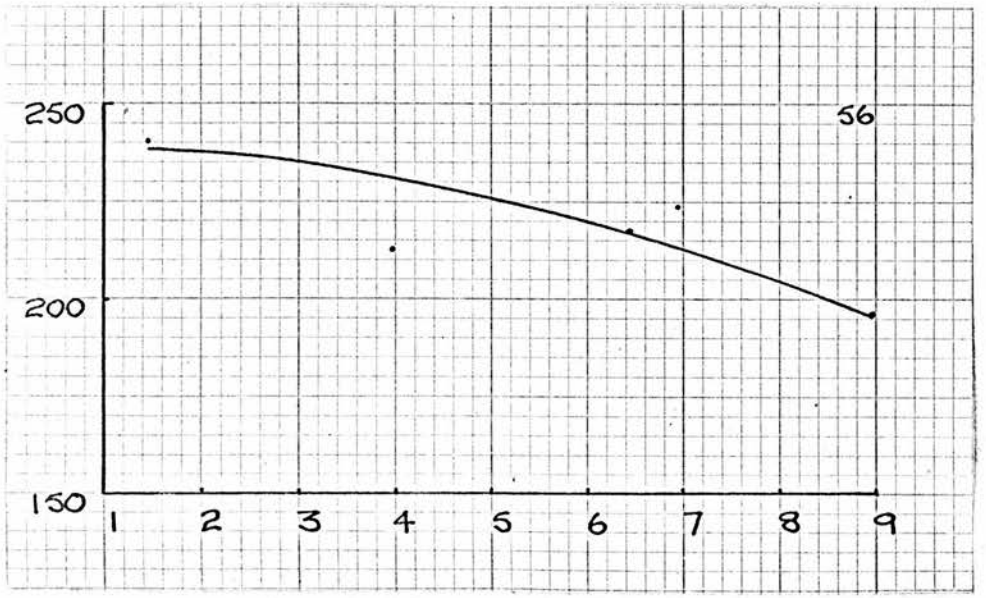


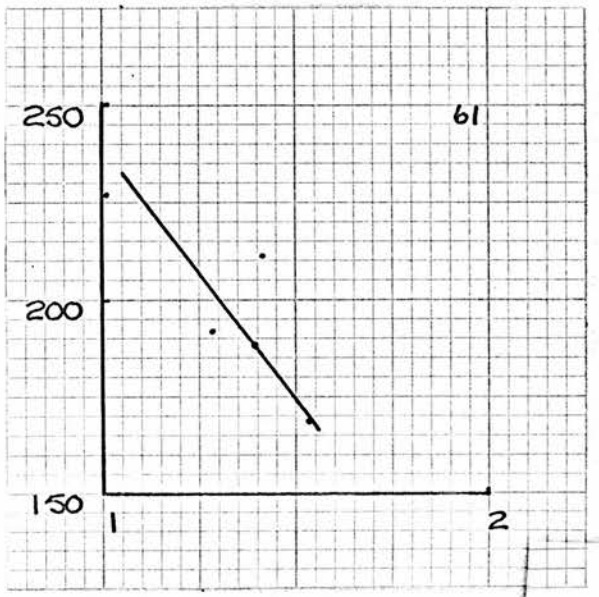


Mean 'reversed' reaction times (blocks of 10 trials) v. Mean conductance changes (blocks of 10 trials)

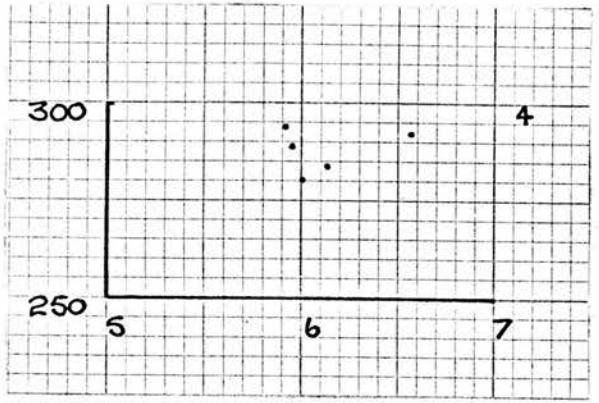


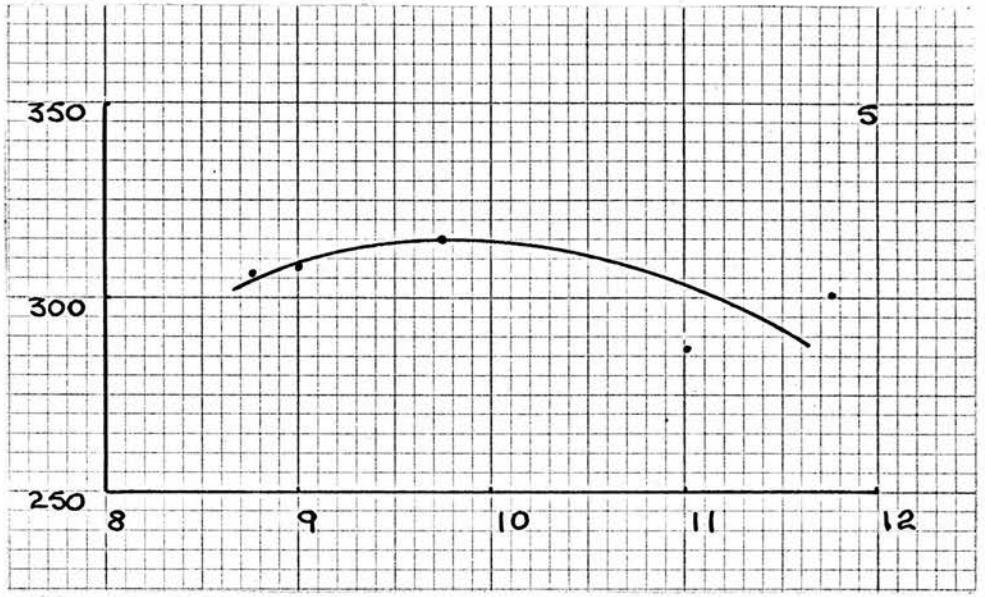


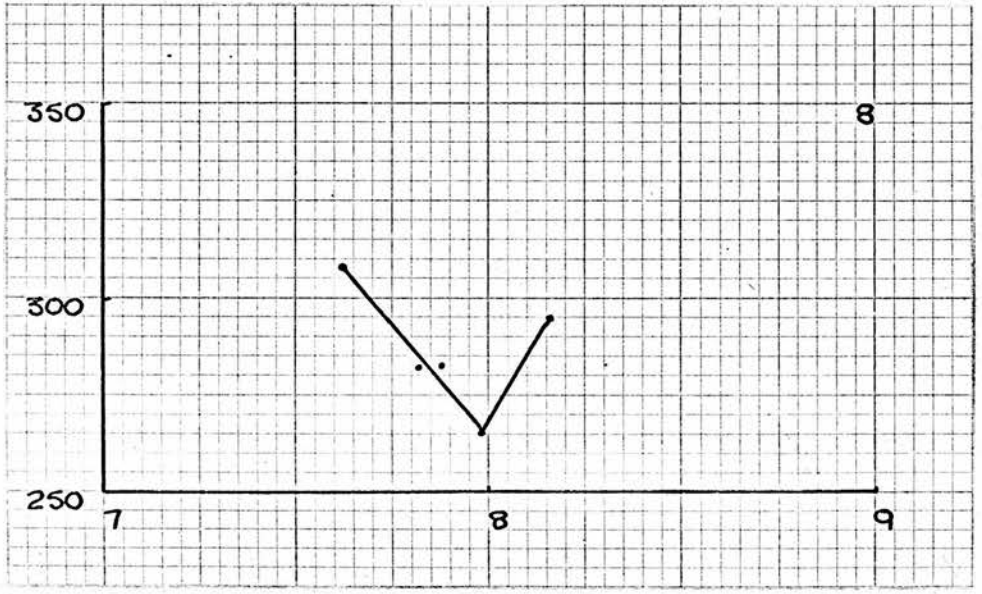




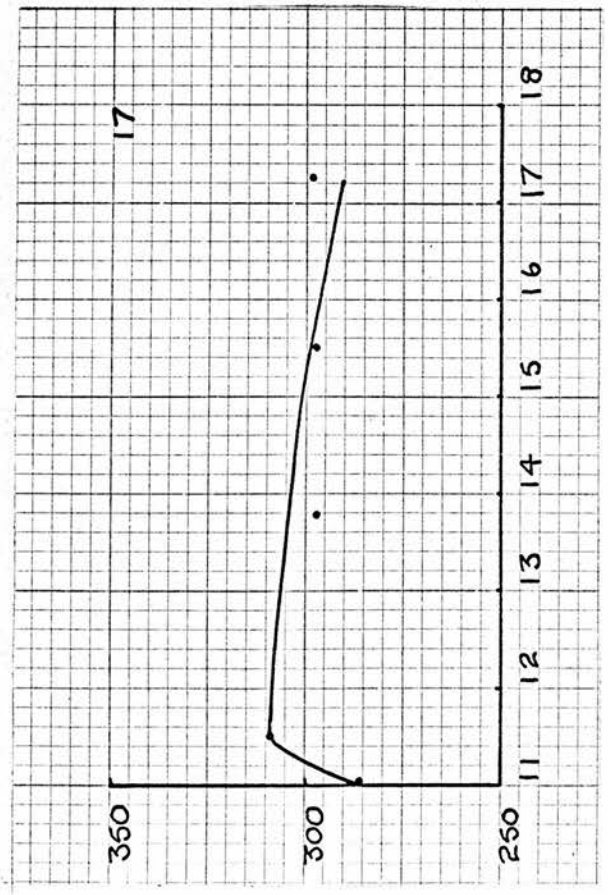
Mean 'reversed' reaction times (blocks of 10 trials) v. Mean basal conductance level (blocks of 10 trials)

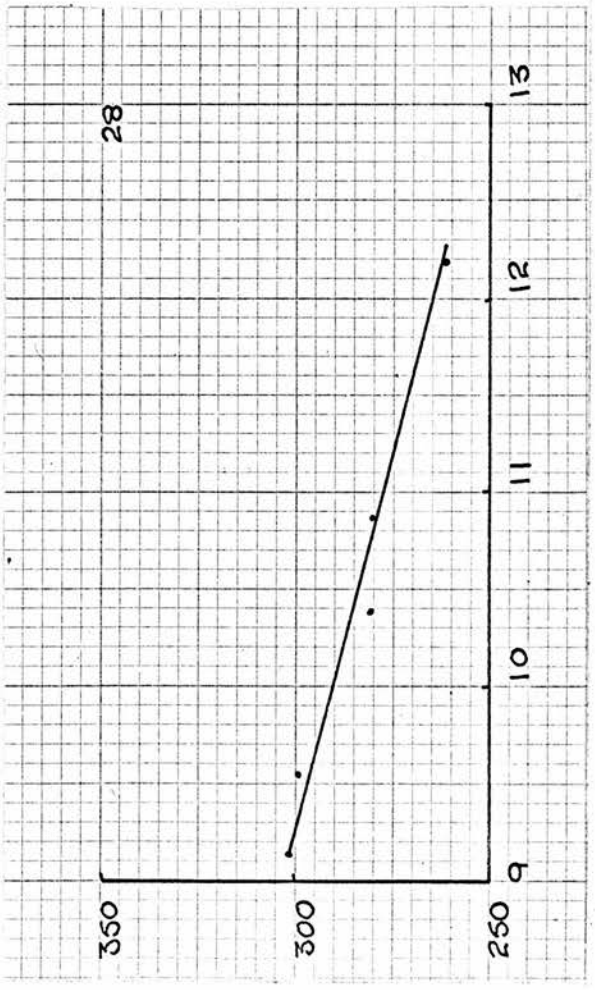


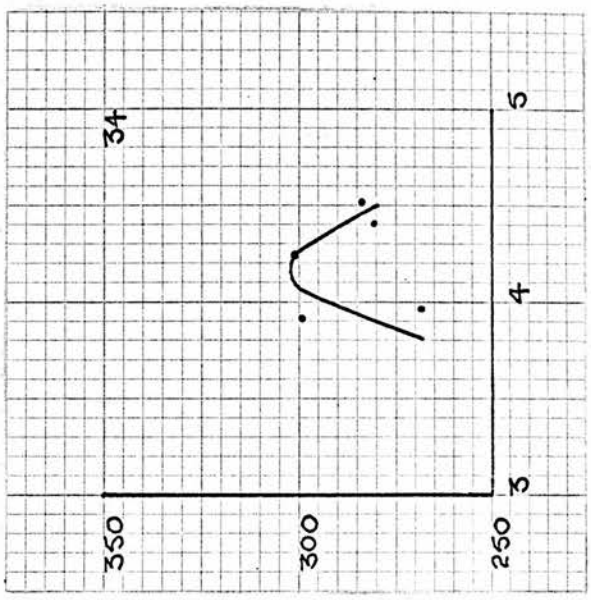


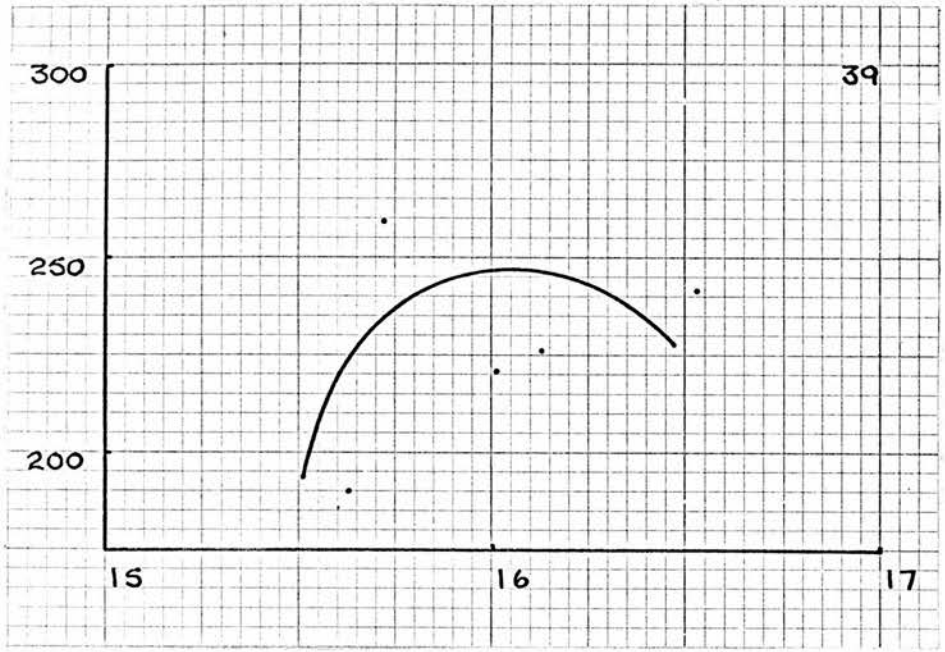


Mean 'reversed' reaction times (blocks of 10 trials) v. Mean basal conductance level (blocks of 10 trials)

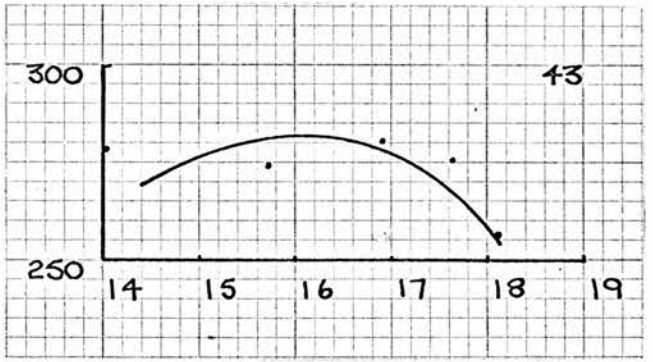


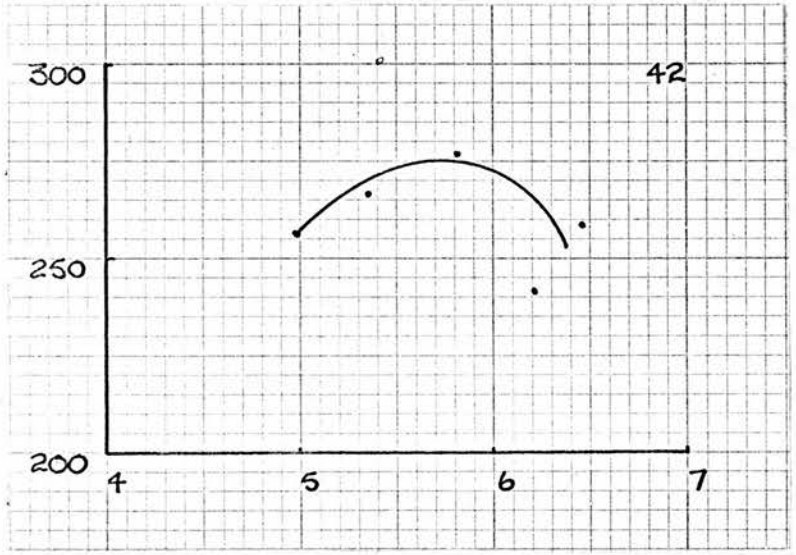


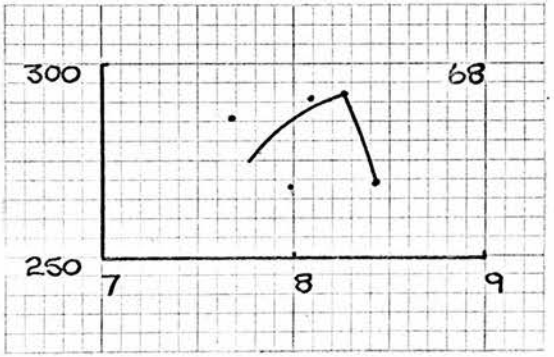




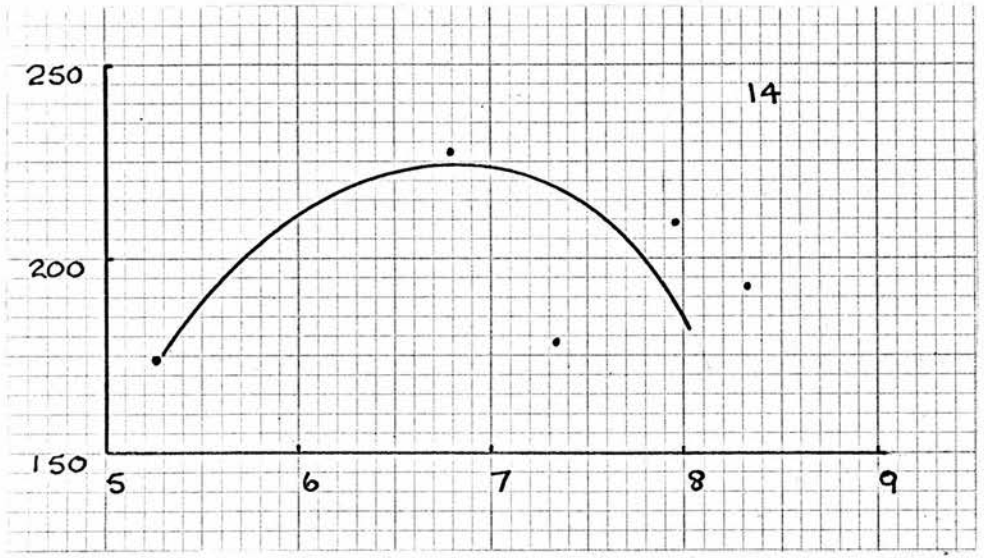
Mean 'reversed' reaction times (blocks of 10 trials) v. Mean basal conductance level (blocks of 10 trials

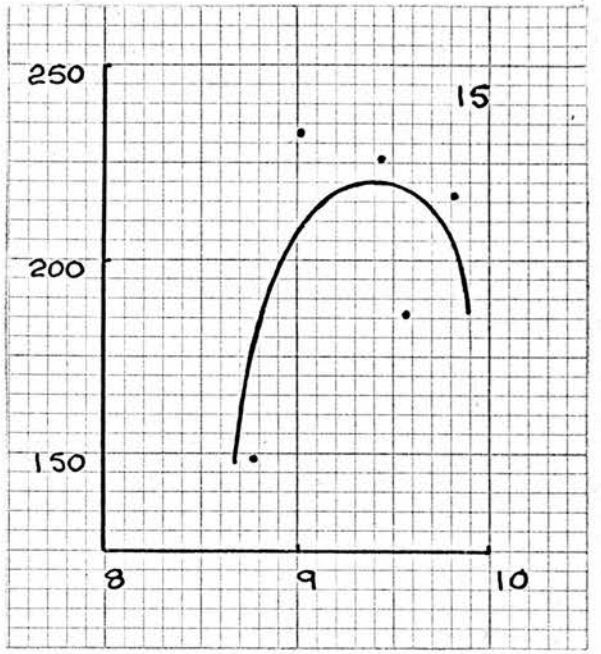


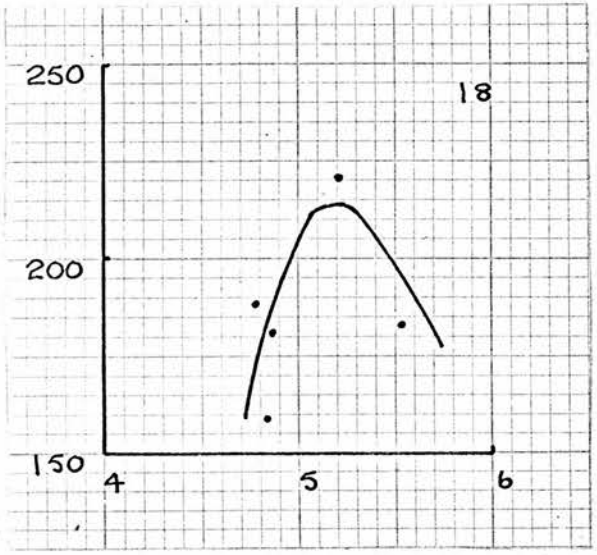


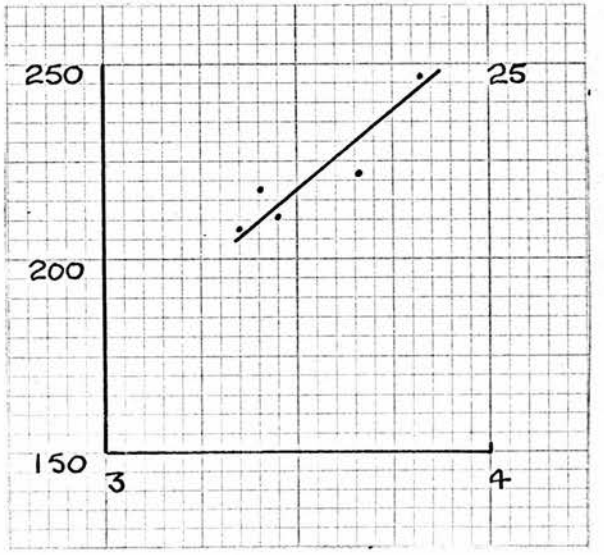


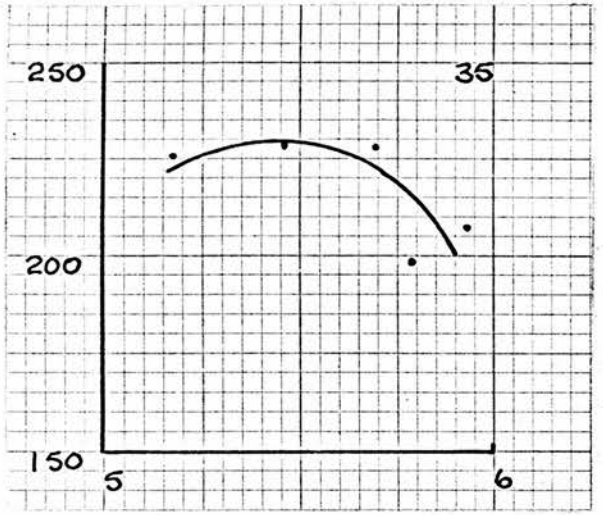
Mean 'reversed' reaction times (blocks of 10 trials) v. Mean basal conductance level (blocks of 10 trials)



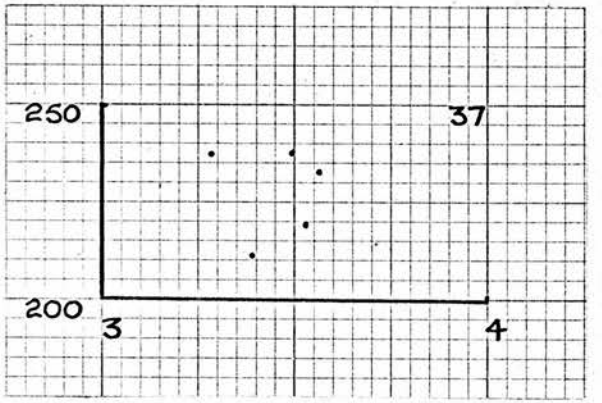


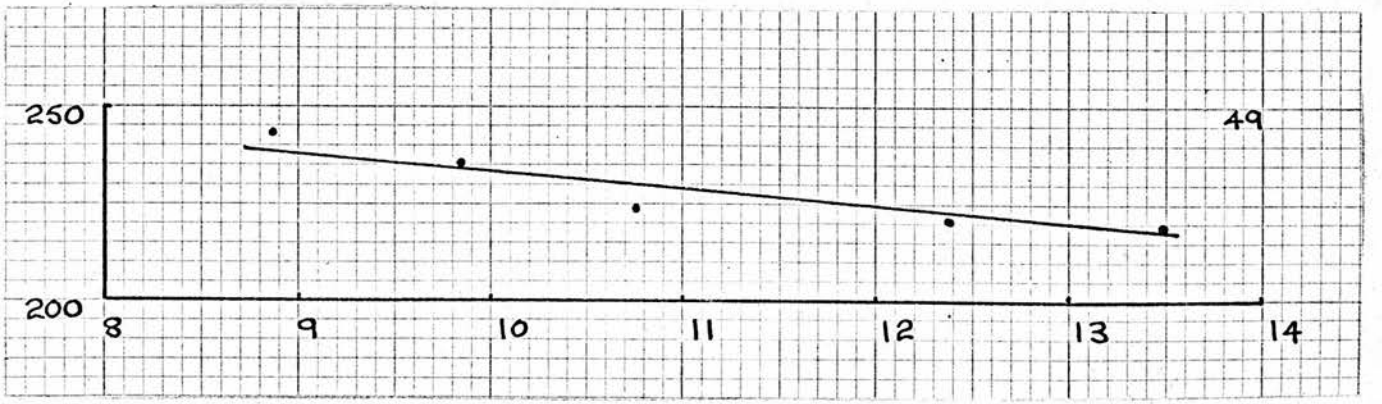




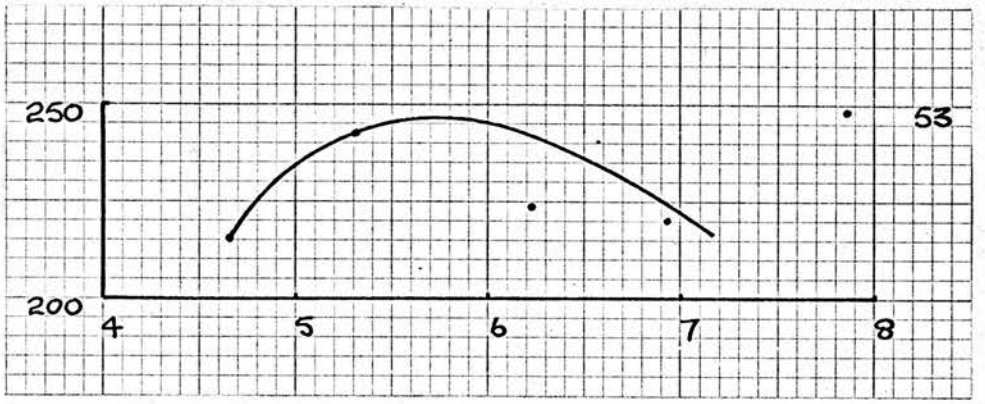


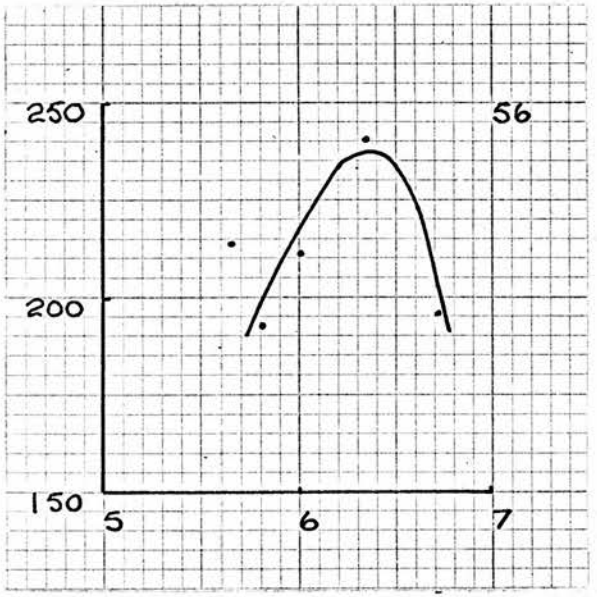
Mean 'reversed' reaction times (blocks of 10 trials) v. Mean basal conductance level (blocks of 10 trials)

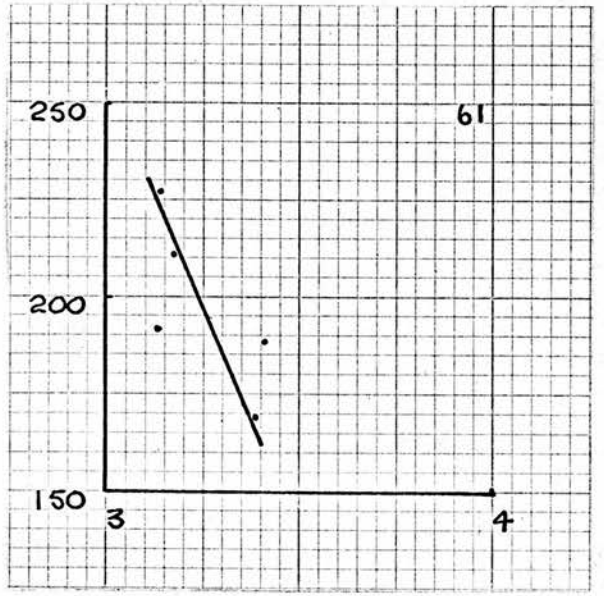




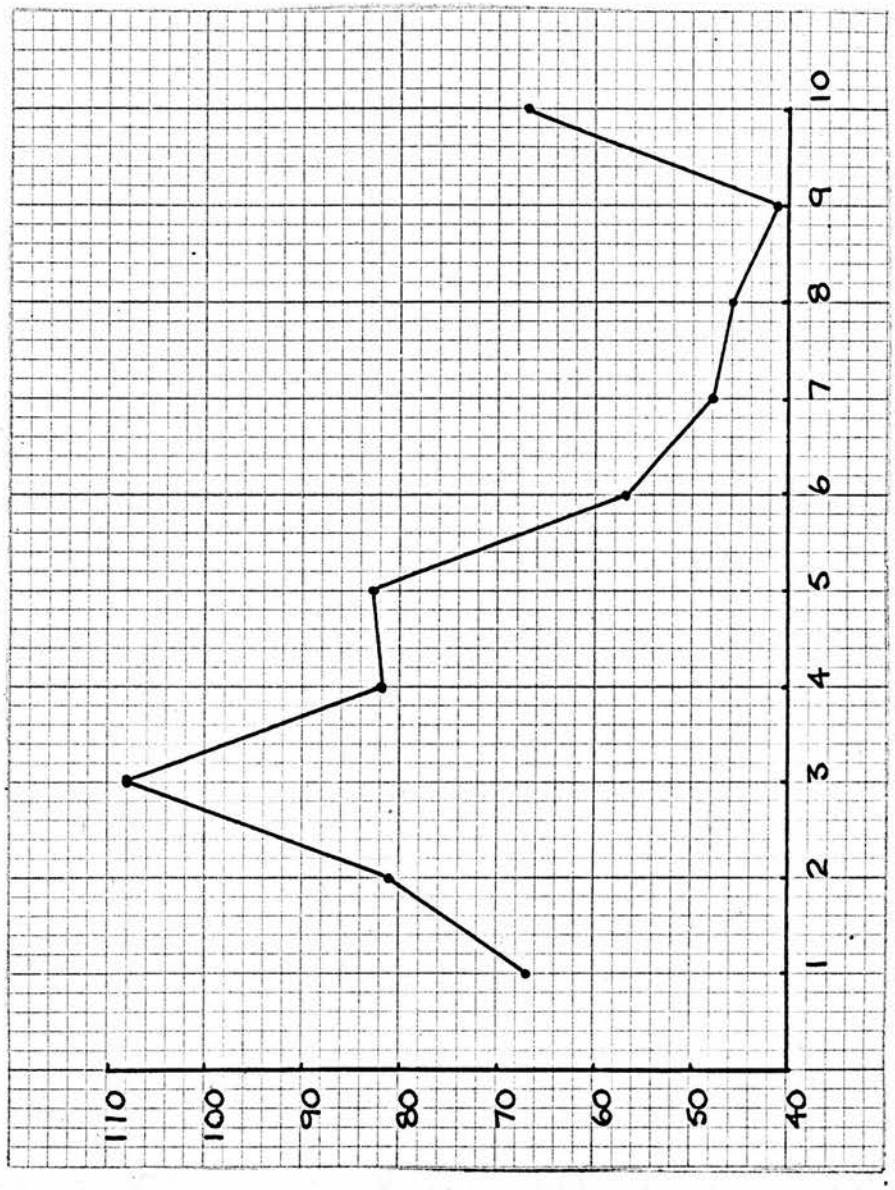
Mean 'reversed' reaction times (blocks of 10 trials)
v. Mean basal conductance level (blocks of 10 trials)



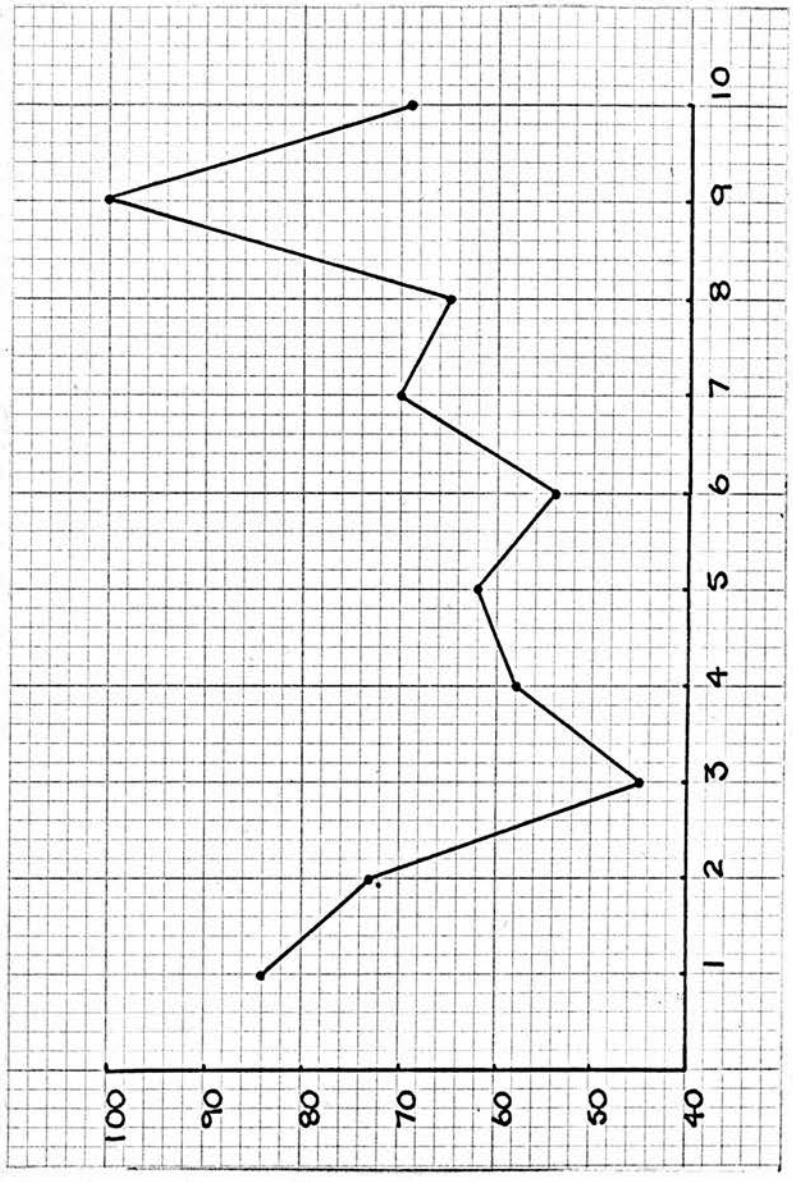




Frequency distribution of the positions (in blocks of 5 trials) of the best ten reaction times



Frequency distribution of the positions (in blocks of 5 trials) of the worst ten reaction times



V DISCUSSION

The basis of any theorising about activation and performance rests on the nature of the reaction processes initiated by the tasks used. Very little is really known of the neurology and physiology of reaction processes and the psychological approaches are many and varied, the most recent being probably those based on statistical decision models and information processing hypotheses. Models and hypotheses which are empirically verifiable, though extremely useful to psychologists in their conceptualising, are sometimes seen to be limited when they are used to make inferences about neurophysiological systems. Leaving aside the fact that most mathematical models currently available appear to be too simple to explain almost all but the most simple observed behaviour, the nature of the terms used in these formulations does not lend itself to close analogy with what is known of the nervous system.

A great deal of what is written about under a heading such as 'the nature of the task' ought really to be considering 'the nature of the individual'. However, it is certainly necessary to consider certain broad aspects of the performance tasks used in the present study before going on to examine relationships between levels of performance and physiological indices. Since the scores obtained on these tasks were used as criterion variables in the analysis of the other, mainly physiological,

variables which were employed, consideration must be given to their inter-relationships.

What superficial similarities and differences do the four tasks employed have? Reaction time and tracking are relatively 'active' tasks, paired associate learning and threshold recognition relatively 'passive' tasks with respect to amount of motor activity required. 'Learning', however it is defined, is involved in the paired associate and tracking tasks and is involved to a lesser extent in reaction time but perhaps hardly at all in the threshold recognition task. Visual and motor co-ordination with a component of speed are involved in reaction time and tracking. Close attention to a presented stimulus and presented stimuli are important in reaction time and threshold recognition. These factors arise, as it were, from the interaction of the individual and the task and some of them must be involved if the task is to be carried out at all. In other words they are necessary for any sort of performance irrespective of its level or quality. They are not of course the only factors involved in performance. Apart from individual differences in physiology, previous experience, motivation and so on, factors such as anticipation and distraction, boredom and fatigue, guessing behaviour, the successful and unsuccessful use of 'systems' and 'tricks', will all affect performance. These latter considerations affect the quality of performance rather than being prerequisites for performance.

The analysis of performance variables shows up some of

the task similarities and differences very clearly. Reaction time and tracking performance, and tracking performance and word learning are strongly related whereas reaction time and word recall are less strongly related. These differences can most readily be explained in terms of the relative involvements of learning and visual-motor co-ordinations in the three tasks. On the other hand, threshold recognition is unrelated to the other tasks and appears from some approaches to be different, though the necessity for close 'attention' perhaps puts it closest to the reaction time task. It is the 'attentional' or 'vigilance' component which is so readily apparent in these tasks which makes them candidates for the positions of activation criteria. 'Vigilance' is usually associated with inactive tasks but the work of Donald Broadbent and others has suggested that all tasks, including active ones, have a 'vigilance component'. The paired associate learning task does not require 'vigilance' in the usual sense of the word, though attention to the material is obviously necessary. The activity required here seems to be mainly 'cortical'. The tracking task presents problems for this sort of interpretation. Once again 'vigilance' is hardly required. Learning is, however, important, but once the 'knack' has been acquired the task is comparatively easy and target contact can be maintained with only minor breaks, until boredom and fatigue set in. However, should learning not be fairly rapid, should the subject not quickly acquire the 'knack' then, on occasion, frustration rapidly follows and the subject, as it were, 'gives in'

to the task. Pursuit rotor tracking, though prima facie a straightforward, easily-assessed task, is likely to be complicated by a number of factors and is therefore perhaps the least likely measure for an activation criterion.

This assessment of the performance variables receives striking support when the physiological variable, basal skin conductance, is considered. Basal skin conductance level is confirmed as a correlate of performance but the degree of the relationship follows the ordering of the performance variables as activation criteria exactly. Thus skin conductance level has a stronger relationship with reaction time and threshold recognition performance, a weaker but nevertheless significant one with paired associate learning and no relationship with tracking performance. The correspondence between the admittedly simplistic psychological assessment of the variables and their strengths of relationship with skin conductance perhaps offers a way out of the vicious circle which 'arousal' explanations often lead to. For example, in discussing vigilance, McGrath et al. (1959) state "to say that performance declined because the vigilance of the observer declined is to follow a circular route of reasoning. Since the state of vigilance must be inferred from the observable phenomena, it cannot then be used to explain those phenomena". In the results presented here however, it is possible to consider not only the level of performance on a particular task and its relationship with a physiological index but also the way in which the performance level - physiological index relationship changes

as the nature of the task changes. The elimination procedure used in the multiple correlation analyses retains resting basal conductance level to the 0.1 per cent significance level as a predictor variable against threshold recognition as criterion and to the 1 per cent level (measured both post-learning and post-recall) for paired associate learning. Similarly in the 'reaction time' correlation analysis resting basal conductance is retained when the equation is tested at the 1 per cent level. Basal conductance measured during the reaction time task, though significantly related to performance, is lost in the elimination. The measure does not appear at all in the tracking score analyses, not giving even the slightest indication of a relationship in the case of resting level and only a very low correlation for level measured during performance. The overall conclusion is that resting basal level of skin conductance offers a moderately good measure of level of performance in those tasks which, it can reasonably be surmised, have a marked 'attentional' component. The validity of the index as a measure of activation being supported, what of its reliability? Table R2, page 138, indicates a moderately good reliability, at any rate over a forty-eight hour period.

As the correlation summary, page 198, shows, another physiological variable which offers itself as a possible performance measure is EMG3, the mean integrated electromyogram level recorded from the upper arm. The evidence is slight. 'Resting' EMG3 recorded during the first five minutes' rest of

Session Three correlates negatively and significantly (beyond the 0.05 level) with both reaction time (reversed) and tracking performance. In the case of the multiple correlation analysis of resting levels and tracking this variable is retained by the elimination procedure to the 1.0 per cent significance level. Restihg EMG3 recorded during Session Two was not retained in the similar analysis of reaction time scores and the correlation for this variable produced only a slight negative relationship (-0.17). The same measure (upper arm EMG) taken during performance gives the very, very low correlation of -0.09 with reversed reaction time and a correlation (-0.236), which just fails to reach the 0.05 significance level, with tracking score. Both tasks being 'active' tasks it is not unreasonable to expect some relationship with muscle activity but the evidence is far from satisfactory. Table R2 page 138, shows a set of somewhat lower reliability coefficients than for basal skin conductance. On all counts such evidence as there is indicates that EMG is not measuring the same aspect of performance as basal conductance level. Only one significant correlation between an EMG measure and a basal skin conductance level measure was obtained. Neck tension level and basal conductance correlated negatively beyond the 0.05 level of confidence, these measures being obtained, oddly enough, during pursuit rotor tracking. It has been noted, Chapter II, page 47, that Eason (1963) found that a neck tension measure was as good as all muscles combined as an indicator of 'effort'. Relationships between the physiological measures will

be considered in more detail below, but it is useful to consider at this point the eyeblink rate measure. A curious hotch-potch of 'significant' correlations is, perhaps, the first reaction when this measure is examined on the summary table. These correlations, however, are exclusively with EMG measures and the two 'active' performance tasks. The discussion of eyeblink rate as a possible arousal measure in Chapter II mentions the possibility of a relationship between generalised muscle tension and eyeblink rate. Support for such a relationship, though slight, was found in the present study. Once again though, the measure has no relationship with basal level of skin conductance and does not appear to measure the same thing.

The one negative and significant correlation (beyond the 0.05 level) between Inspiration - Respiration ratio (or I-fraction) measured post-recall and paired associate learning performance, does not receive the slightest support, even from the similar post-learning measure and is, very likely, a chance result.

One more interesting result remains to be considered in the examination of physiological measures and measures of performance. This is the significant correlation between mean GSR latency and reaction time; long latency, slow reaction time, a result which provides encouraging support to Surwillo's speculation (Chapter II) that this might be an activation measure. The surprising feature of GSR latency is however the degree to which it correlates with other physiological measures and the way in

which the correlations fit in well with the 'ordering' in terms of amount of intercorrelation of the physiological variables. The possibility of this being a 'general index' is discussed below. This exhausts the physiological variables as indices of performance and leaves us with the personality dimension variables.

The N scale score[1] attracts immediate attention for its highly significant, negative correlation with paired associate learning performance and its lower negative correlation (well beyond the 0.05 level) with tracking score. Immediately, the 'learning' components of these two tasks must be considered as the common factor operating here. This, together with the fact that N score appears not to be related to any other variable used perhaps indicates that it is not measuring the 'activation' aspects of performance, but something else.

Corteen's description of the N scale as an 'adequacy' dimension (see Chapter II) and his rejection of the notion (supported by empirical findings) that it is in any way related to activation is in line with the present findings. Corteen generalises the situations in which performance has been

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[1] In an early analysis subject identification number was, in error, run as a variable in a correlation program. N scale score was found to correlate with it beyond the 0.05 significance level. The temptation to suppress this accidental finding has been overcome. It illustrates nicely the question of 'belief' in the results of psychological experiment, discussed by Lykken (1969). The sequence of subject identification numbers follows, with one or two exceptions, the order in which the subjects were run. The hypothesis that more stable personalities tend to volunteer for psychological experiments in early and mid-summer, whereas neurotics favour autumn and winter has been rejected.

compared with N score as those "which require complex patterns of overt response". An examination of the tasks used shows that they are essentially learning tasks, the conditions under which learning was required being manipulated. It would be mere presumption and speculation to replace the term 'adequacy' with something like 'learning competence' - as well as being inelegant - but a test of the range of this dimension by examining performance on complex tasks already fully learned by the subject and on tasks which require learning might help to define the concept more accurately.

The dimension of introversion/extraversion identified as it is in Eysenckian terms with the concepts of inhibition and excitation would lead to the prediction that individuals scoring high on the E scale would be relatively poor learners while those scoring low would be relatively good. Learning, conditioning and memory are among those mental processes which are facilitated by cortical excitatory processes and impeded by cortical inhibitory processes. The present study gives some support for the E scale score being used as an index of these processes. A correlation coefficient of -0.29 significant beyond the 0.05 level was obtained between recall score and E scale. In the case of E scale and tracking performance the correlation though in the right direction was not significant. Smith's (1968) finding of a correlation between auditory threshold and E scale was not confirmed for visual recognition threshold but an interesting relationship between E score, threshold and figure reversal rate,

all of which have been discussed in terms of cortical inhibition, was revealed in the factor analysis. The second factor brought out by the principal components analysis of the performance variables has substantial loading on these three measures. Smith appears to favour the interpretation of E scale within an arousal framework. An examination of this measure and resting basal skin conductance for example, shows correlations in the right direction and approaching, though still well short of, significance at the 0.05 level. If N scale were to be reinterpreted in terms of learning then E scale which is certainly not measuring the same thing cannot be so interpreted. E scale may provide, in some situations, a paper and pencil measure of arousal but this possibility needs to be treated with a good deal of caution.

It has been shown that the tasks used in the experiments are related and the speculation that it is their learning and attentional components which provide the links and differences has been advanced. Basal level of skin conductance has support as an index of performance on those tasks with a major attentional component.

A problem may arise here unless 'attention' is defined with care. If attention is regarded as some sort of ability possessed by the individual whereby he can operate in a consistent fashion such that irrelevant stimuli do not interfere with a particular course of action, then 'directional' as well as 'intensive' aspects of performance need to be considered. These aspects are usually specifically excluded from any account of

activation. Further, attention and vigilance are often concerned with selection of appropriate stimuli to which the individual has to respond. Considered within an activation framework this stimulus-bound, respondent state of vigilance would most appropriately be dealt with under the heading of short-term or phasic arousal. Such evidence as there is indicates that basal skin conductance level is an adequate measure of long term activation and yet a not unreasonable interpretation of the present data might link it with attention. Resolution of these problems lies in looking at what is meant by attention in any particular situation. It then becomes apparent that no one simple function or concept is implied by the word 'attention'. Each situation has to be considered in terms of the stimuli and responses involved as well as the attitudes of the subject, before inferring levels of hypothesised states of emotion, activation, arousal, vigilance and so on. In the present study, the tasks have been considered in terms of the demands of the situation on the subject, primarily of learning and attention. These concepts, however defined, it is suggested, are necessary for any performance at all. Such clues as have been provided by the present study might suggest that a large scale investigation designed to discover which task performances are related to basal skin conductance would enable us to set up an operational definition of attention. The present state of affairs in which 'activation level' is invoked to explain any sort of relationship between any performance and any physiological measure does nothing more than confuse the issue.

If activation level is to mean anything at all then its interaction with various types of performance and various phases within complex performances must be considered. For example, it has already been noted (Chapter II, page 31) that the sensory aspects of a vigilance task are not likely to be affected by arousal level. Signals used in vigilance tasks though they may be weak are easily detected by a so-called alert observer. The efficiency of the observer in this situation is different in kind from the threshold task where there are individual differences in threshold value. Differences in the tasks can be obscured by merely recording 'hits' and 'misses' and by vague references to 'level of efficiency'. In other situations response variables are likely to be affected by arousal level when this is defined in terms of behavioural intensity, for example, speed of response in the reaction time task. Here is a task where 'attention' and 'alertness' are required but which is not usually described in the same way as vigilance tasks are because the experimenter is interested not in whether or not the subject responds to the stimulus but in how fast he responds.

Recent work in signal detection theory has shown how important motivating conditions and instructions to the subjects are in determining an individual's 'threshold'. Manipulating these conditions affects performance on all kinds of tasks and is sometimes described as affecting levels of attention (or activation). The argument goes on from here to describe how motivational and situational manipulations might affect

postulated physiological centres and systems and the inevitable two-factor theory emerges. However, without some means of specifying fairly precisely the motivational and situational manipulations so that they may be compared with physiological activity arising from or controlled by these systems, empirical verification of the theories becomes difficult. No matter how carefully the manipulations are controlled, it is not possible to be sure that they are affecting subjects in the same way. Sometimes subjects are asked how they 'feel' but this procedure seems to be frowned upon by hard experimentalists. The difficulty is not confined to field of activation. (How many compilers of lists of 'taboo' words have been to a football match or visited a men students' club? These words do not seem to be 'taboo' in those situations, though they are in the presence of women and clergymen).

In experiments on arousal and activation attempts are made to manipulate the level of these influences on behaviour by inducing fear, rage and most frequently of all, stress. But stress means different things to different individuals and what is stressful to one individual is not necessarily stressful to another. How often is 'stress' really induced by showing the average student subject a 'stressful' film in the laboratory?

The fact that inter-individual comparisons of physiological indices have but rarely shown any relationships whereas intra-individual studies show consistencies, is the basis of the notion of autonomic response patterning or specificity. However

this concept is not clear. Lacey et al. (1953), for example, have demonstrated that the specificity is idiosyncratic. Wenger et al. (1961) show that the patterns are specific to the particular stimulus situation. In other words we can account for specificity in two entirely different ways and ways which in most situations are likely to interact. A number of attempts have been made to manipulate subject 'involvement' in experimental situations (Dawson and Davis 1957, White 1965). These have shown that levels of involvement do have differential effects on autonomic responses and hence on autonomic response specificity.[1] The interesting speculation then arises as to how much specificity is in fact a function of subject-situation interaction and that if in a multi-measurement study this was somehow kept roughly constant whether the physiological indices would intercorrelate. Attitudes of the subject to the situation and his ability to control the situation and even to some extent his physiological responses[2] would be important. Pribram's (1960) TOTE sequence describes how the organism might exercise control over what is and what is not stimulation.

Murrell (1967) citing neurophysiological studies which

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[1] Notterman and Trumbull (1959) describe a servo-system model in which physiological responses may change the stimulus by changing its impact on the organism so that with each successive reaction the stimulus conditions vary. Such a system introduces yet another variable which would affect specificity.

[2] Stern and Lewis (1968), for example, found that 'method' actors showed a higher degree of voluntary control over their GSR's than 'non-method' actors.

have shown that 'self-arousal' i.e., the sustaining of wakefulness by stimulation of the reticular formation by impulses arising in the cortex, is possible, proposes yet another hypothetical system, that of 'auto-arousal'. The mechanism is of interest in the present discussion because Murrell suggests that it operates when the "individual 'makes up his mind' to do well in a task". He is naturally reluctant to equate this with motivation and prefers to define it in physiological terms as "cortical activation resulting from stimulation of the reticular formation by the cortex, this stimulation being under voluntary control". Once again the emphasis is on the subject-situation interaction and this is what many studies neglect. What then of a situation in which a number of physiological indices were recorded and in which some moderate intercorrelations were obtained? Such a state of affairs existed in the present study.

At all stages, the subjects were kept informed of what was going on and over the three sessions became quite used to the situation. They all received a small monetary reward and were encouraged to do well in all the tasks. The overwhelming majority of the subjects appeared to be keen to do the experiments and asked many questions about the study and the operation of the equipment. They appeared to be impressed with the array of apparatus and recording equipment and were not overawed by it. They were also allowed to inspect their chart records at the end of each session. Only in the second and third sessions was the full set of eleven electrodes attached by which time they had spent

one hour doing experiments in the laboratory and learning about the broad plan of the study.

Basal skin conductance was found at one time or another to correlate with every other physiological measure used except the I-fraction measure, eyeblink rate, and the number of GSR's evoked by the warning light in the reaction time task. The findings of Silverman et al. (1959) of an inverse relationship between the number of spontaneous or non-specific responses and basal resistance level received some slight support. A non-significant relationship, though in the right direction, was found for the data collected in Sessions One and Two and a relationship significant at the 0.05 level was noted for the Session Three data.

As the summary table shows, heart rate, in addition to its correlation with basal skin conductance correlated with all the EMG measures at some stage and also with respiration rate, I-fraction and GSR latency. By inspection of Figure 8 (page 195) it can be seen that respiration rate, the I-fraction and the GSR measures, with one notable exception, showed few correlations with other variables. The notable exception was GSR latency. It correlates negatively and significantly with basal skin conductance level (-0.520) and heart rate (-0.403), and shows no relationship with the EMG measures or the respiration measures. Its correlation with Best 10 RT (reversed) is better than that of basal skin conductance with the same measure. This index may be as good a general measure as basal skin conductance.

It is not the intention of the present writer to add to the numerous speculations on the mechanisms and neural structures involved in activation. On the one hand, all the findings of the present study could be incorporated in the existihg framework of ideas on reticular formation function; on the other, since our knowledge of the neurological systems is far from complete any psychological theories based on them must be deficient and possibly erroneous. Although the correlation and factor analyses of the physiological variables indicate only modest relationships the evidence is against treating them as separate dimensions. This feature of the present data together with the likelihood that no one physiological measure will be sufficient to give a comprehensive picture of the autonomic nervous system and its function, make generalisations about the system based on a single variable rather suspect.

However, since little has appeared in the psychological literature regarding GSR latency perhaps in this instance a few tentative suggestions might be permitted.

The problem lies in relating latency to activity in any hypothesised central alerting system since the major portion of the latency period is apparently accounted for by changes at the periphery. The sweat glands are certainly the effector organs of the GSR and the preganglionic sympathetic sudomotor neurones are its final common path in the spinal cord. The latency of the GSR includes the conduction time along these

fibres and along the post-ganglionic sympathetic fibres and also the delay at the neuroglandular junctions. Experiments reported by Wang (1957) in which GSR's have been evoked in the cat by direct stimulation of the postganglionic sympathetic fibres have shown that the response depends upon the summation of the individual and independent reactions of many separate units, each unit consisting of one axon and its effector cell, and each unit having its own threshold and velocity of reaction. The latent period gives the duration from the moment of applying the stimulation to the moment when the fastest reaction units come into action.

Patton (1948) has shown that the long latency is mainly due to delay at the neuroglandular junction.[1] It is possible to speculate that an increase in the number and velocity of active reaction units indicated by an increase in the amplitude of the GSR accompanies an increase in activity in the reticular facilitation area and that at this level the activity persists for a time. Differences in this activity level (following 'classical' activation theory) affect performance level. The link between central and peripheral mechanisms may be provided by increased blood supply.

Cannon (1929) demonstrated that painful and emotional

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[1] Although the conduction speed of the post-ganglionic fibres is relatively slow this cannot account for the long latency of GSR.

stimuli produce a combination of autonomic reflexes which facilitate movements of skeletal muscle - a 'preparing for action' effect. The combination of reflexes was mainly concerned with the regulation of blood supply to the various parts of the body (increasing the supply to the skeletal muscles and decreasing the supply to the alimentary system, for example). It may be that it is variation in the blood supply to the postganglionic sympathetic neurones and/or their axones which ultimately determines the size of GSR, for Wang (1958) has shown that asphyxia produced by occlusion of the abdominal aorta causes more and more of the reaction units to be put out of action. There is thus a decrease in the intensity of the response. As asphyxia proceeds, the velocity of each reaction unit is slowed down before ceasing to function, causing lengthening of both the latency and the rising phase of the response. It is quite possible that the reverse process may occur. The more efficient or increased the blood supply to skeletal muscles the more behavioural responses will be aided and a similar level of supply to the sympathetic nerve chain may result in a relatively shorter GSR latency. There would also be relatively greater GSR amplitude. Results from the present study indicate that the mean conductance change of responses measured during the reaction time task correlate negatively and significantly (-0.44) with GSR latency.

There is an increasing interest in temporal aspects of responses to discrete stimuli (see, for example, the section with this heading in Rosenblith and Vidale (1962)) but this interest

has been mainly concerned with the study of evoked potentials. If further work supports the data obtained in the present study the field of research may be widened to include examinations of the phase relationships between many different types of electrophysiologic phenomena and observed behaviours. That the problems are likely to be many is illustrated by another finding of the present study (Chapter IV, page 205), a finding which in no way helps the speculations presented above. It is that GSR latency did not discriminate between different levels of performance within subjects or between subjects, when means of either the latencies associated with the warning lights accompanying the best ten or the worst ten reaction times were considered.

The factor analyses described in Chapter IV, pages 147 to 159, show the existence of a muscle tension factor, though the evidence for a general autonomic factor is less clear. Nevertheless the principal components analyses do highlight relationships between the variables. All in all these inter-individual analyses show more intercorrelation of physiological variables than appear to have been found in previous studies. Most of these studies have been concerned with emotional states, stress, anxiety and so on, identified by paper-and-pencil tests or occasionally merely by assumption or assertion. That the true state of the subjects was not so easily identifiable and indeed was not identified is a possibility that needs to be considered when the lack of intercorrelation is examined. At best this could be done by using telemetry equipment for twenty-four hour

monitoring and examining 'mood' states over a period of days. Less ambitiously the state of 'affective arousal' of a subject might be examined before and after experimental sessions, perhaps by questioning by a 'stooge' fellow subject. Finally non-stress, 'non-emotional' studies should aim, as did the present one, at repeating the measurement of physiological variables not only to check their reliability but also to allow subjects to become used to the situation and become more involved.

The results of the multiple correlation analyses must stand for themselves as an indication of how well the indices used might predict performance on the tasks investigated. The 'best' of the indices in terms of their correlation with the various performance levels have already been discussed. Although it is difficult to directly compare the regression equations and corresponding multiple correlation coefficients because of variations in the number and type of predictor variables used in each analysis, one general conclusion may be drawn. This is that the physiological variables 'explain' relatively more of the variance in the case of the passive tasks than in the active tasks. In the case of reaction time (and almost certainly of tracking, though here a direct comparison was not carried out) resting levels of physiological indices are as efficient predictors as measures taken during or in the preparatory stages of activity. The elimination analyses in general confirm the original correlational relationships leading to the conclusion that for predictive purposes a few well chosen indices are likely to be of as

much value as a battery.

The results stand and the study and this discussion must stand by them. It has not been the aim of this discussion to explain the results in terms of a new speculative physiological theory - they can readily be fitted in to existing views. Admittedly the inverted U-shaped curve was not found in the inter-individual analyses for plots of the data showed no evidence of curvilinearity. However, this was expected, the aim of the study being to keep level of arousal - affective arousal that is - constant for all subjects and not try to manipulate it in any way. The few studies that have been reported suggest that in this sort of a situation linear relationships between level of physiological activity and performance are found.

The intra-individual analyses showed some evidence of curvilinear relationships between basal conductance and reversed reaction time and between mean conductance change and reversed reaction time. A possible explanation for the generation of the inverted U-shaped curve has been discussed (Chapter IV, pages 203 to 205). Suffice it to say that an explanation in terms of activation level variation is not justified. Cofer and Appley (1964) discussing activation and emotion assert, "While there is a certain plausibility and reasonableness in activation theory, it is hardly appropriate to call it a theory. As we see it, its major tenet, aside from the assertion that emotion means arousal, is that there is a curvilinear relationship between behavioural efficiency and measures of physiological arousal - a tenet of

high theoretical neutrality".

Drive, as Hebb and Malmo see it, is synonymous with arousal and drive theory in this sense has largely ignored individual differences and affective components. Two-factor approaches stressing short-term and long-term components of drive have contributed to the development of activation theory within the general framework of motivation. The problem then becomes one of attempting to separate the two factors and to objectively measure them. The suggestion that conductance change measures short term arousal while basal conductance reflects long term tonic arousal has been put forward and has received some empirical support. Because basal conductance level and conductance change have not been reported as being related the assertion that they cannot both be measures of the same aspects of activation might be made. However, conductance change was suggested by Lacey and Siegel (1949, and see Chapter III, pages 84 and 85) as a measure of GSR <u>because</u> it was a unit which appeared to be independent of basal conductance level. But in the present inter-individual study mean conductance change was found not to be independent of basal level, significant correlations between the two being repeatedly found.

This does not argue against the two (or multi) factor theory of activation but it does mean that we must approach the identification of the factors in terms of different physiological response systems with some caution.

From the point of view of psychology it is the

behavioural aspects of activation which have most interest. However, the sustained interest in activation theory has resulted from the physiological findings which have been revealed and developed notably by workers such as Lindsley. Behavioural research is somewhat inconclusive and the present study is no exception. Psychologists must look to the neurophysiologists for guidance as to the importance of various neurological systems in determining 'peripheral' physiological phenomena. In the meantime the investigation of the circumstances, situations, types of task, subject attitudes and so on, in which physiological indices and behaviour do seem to be related can be continued. The present study has demonstrated a number of relationships between and within performance levels on a set of tasks and physiological indices. If physiological theorising is to be left for the physiologist (with an allowance for moderate speculations by the psychologist and possibly immoderate speculations by the psychophysiologist) the important task for the behavioural scientist is to attempt to specify dependent performances in terms of all the processes which affect them. In this way, the processes and the neurophysiological systems can be linked and inferred states of activation, motivation, emotion and the like will have real meaning.

To summarise: inter-relationships between reaction time performance, tracking performance and paired associate learning were found. These variables together with performance

on a threshold recognition task were used as the dependent variables in a series of multiple correlation analyses. An attempt was made to assess these tasks as candidates for activation criteria.

A selection of physiological indices was examined, recordings being made both at rest and during performance. Modest but reasonably reliable relationships were found between the electrodermal measures, between basal level of skin conductance and heart rate and between heart rate and respiration rate. Measures of muscle activity taken from three sites were found to be inter-related. Although some inter-correlation was observed the muscle tension measures did not show much covariance with the other physiological measures.

Inter-correlations between the variables suggest that they cannot be dealt with independently in the study of autonomic reactivity. A possible reason for the inter-relationships observed here was that no attempt was made to vary level of arousal in the subjects. Indeed every effort was made to ensure that the subjects became familiar with and at ease with the laboratory situation. The possibility of a general autonomic factor which can be assessed by the measurement of peripheral physiological indices received some support.

A number of relationships between the physiological and performance variables was observed. Basal level of skin conductance was found to relate to three of the four performance variables. N scale score was found to relate to tasks

having a learning component. Multiple correlation analyses showed the extent to which the physiological and personality variables employed might be used as predictors of performance. The utility of basal level of skin conductance was confirmed. GSR latency appeared to have a moderately good relationship to reaction time performance and also to be related to basal conductance, mean conductance change and heart rate. This variable might merit further study.

Basal level of conductance seems to be a moderate predictor of performance on tasks which involve 'attention' - other things being equal. Studies which attempt to keep 'other things equal' and which involve the measurement of skin conductance and the assessment of performance may help to confirm this physiological index as an operational definition of attention or arousal level. It appears that if we regard level of performance as an intensive aspect of behaviour and link this with level of activation then basal skin conductance level is a measure of activation.

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APPENDIX 1

TABLE D1

VARIABLES

01 Mean of the best ten reaction times (Best 10 RT).

02 Standard Deviation of reaction time (S.D. RT).

03 Pursuit rotor tracking. Time on target (Tracking Score).

04 Word recall score (Recall Score).

05 Threshold scores (Threshold Score).

06 N Scale scores (N Score).

07 E Scale scores (E Score).

08 Overall mean figure reversal rate (Overall FRR).

TABLE D1 **Variables**

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08
01	214.4	31.4	065.3	09.5	3.5	15	10	13.8
02	197.7	63.9	141.2	21.0	3.0	10	13	29.2
03	224.4	54.3	138.8	17.0	3.3	02	13	08.4
04	185.1	21.5	229.6	27.0	3.7	03	11	15.2
05	190.3	28.9	148.4	10.5	3.5	08	11	08.6
06	232.6	21.3	036.3	13.0	3.7	11	12	21.2
07	201.5	23.1	162.4	25.0	4.0	04	07	15.2
08	188.9	56.6	160.6	09.0	3.5	07	17	11.3
09	228.2	49.2	042.5	15.5	3.8	02	16	15.3
10	226.9	68.7	018.3	18.0	3.3	12	14	24.2
11	203.8	23.7	126.9	19.0	3.0	07	14	17.6
12	205.5	52.3	034.5	06.0	4.5	07	13	09.5
13	214.4	45.1	038.4	11.0	4.7	13	17	26.4
14	251.3	48.2	056.3	25.0	2.5	03	05	14.7
15	238.1	52.7	064.7	12.0	4.0	06	12	07.9
16	199.9	34.7	072.8	16.0	2.8	04	11	10.1
17	181.9	21.3	250.7	22.0	3.3	05	18	20.2
18	249.4	62.1	030.7	07.0	4.0	17	15	08.8
19	215.3	38.2	064.7	16.0	4.2	10	10	05.3
20	205.8	47.6	043.4	10.0	3.2	12	13	17.8
21	210.1	52.9	025.7	06.5	4.5	13	16	06.3
22	220.8	26.7	004.2	12.0	3.5	06	19	14.4
23	197.3	32.7	174.2	25.0	2.8	08	14	07.7
24	201.7	30.3	158.4	14.0	3.8	15	16	09.3
25	252.1	38.3	003.9	07.0	3.3	12	15	08.2
26	223.1	50.8	044.9	07.0	3.5	07	16	19.4
27	212.4	35.5	014.5	19.0	3.3	15	11	15.2
28	185.0	38.7	157.0	06.0	4.3	16	19	26.5
29	218.3	34.8	022.0	16.0	4.3	07	20	09.9
30	222.2	42.2	070.1	09.0	5.0	14	11	00.8
31	227.5	49.8	063.8	06.0	3.0	14	09	08.2
32	223.6	23.9	044.9	17.0	4.7	05	18	18.4
33	216.3	22.6	111.4	15.0	4.5	08	13	19.3
34	182.6	43.2	080.4	08.5	4.7	12	18	11.4

TABLE D1 cont. Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08
35	253.4	26.1	007.8	05.0	6.0	13	13	15.8
36	220.2	36.3	175.3	15.0	3.0	09	06	19.5
37	246.4	38.8	012.4	04.0	3.7	07	12	17.9
38	204.4	44.1	143.9	14.0	6.0	14	08	13.4
39	191.9	75.3	090.8	22.0	2.5	03	15	19.9
40	214.1	40.3	052.5	11.5	3.5	07	06	03.5
41	208.7	37.4	019.6	18.5	2.7	07	14	20.8
42	196.0	40.2	053.9	13.5	2.7	16	07	23.1
43	197.0	33.4	072.4	15.0	3.2	11	16	11.6
44	213.2	52.8	003.4	17.0	3.0	09	17	07.6
45	198.3	29.4	120.8	25.5	3.3	10	03	13.2
46	208.7	27.7	070.1	10.0	2.7	06	13	28.8
47	219.1	48.1	030.4	14.0	2.3	10	15	06.8
48	205.0	49.0	020.6	18.5	3.8	08	14	10.9
49	234.8	39.9	034.2	14.0	3.0	10	12	32.6
50	201.5	57.2	071.9	07.0	2.8	07	11	17.7
51	205.5	44.6	194.8	14.0	3.2	08	12	15.4
52	197.0	35.5	169.1	16.5	1.5	07	15	47.8
53	233.9	31.2	171.0	14.0	4.7	07	11	10.8
54	223.4	46.6	094.0	18.5	4.0	11	07	11.8
55	226.4	29.6	071.7	06.0	2.7	15	16	13.0
56	238.1	36.0	035.7	07.0	3.2	16	19	22.8
57	215.2	53.0	014.4	04.0	2.3	18	16	12.8
58	197.2	35.2	107.9	07.0	2.3	15	16	08.5
59	214.8	22.7	077.1	08.0	2.3	13	13	12.5
60	206.0	30.7	074.7	09.5	2.3	11	17	30.9
61	235.3	59.2	019.5	12.0	3.5	12	20	10.3
62	220.8	51.2	075.0	09.0	3.3	07	11	20.7
63	230.8	51.4	051.7	19.0	3.0	09	10	24.5
64	206.0	27.7	108.5	18.0	2.5	07	17	19.2
65	226.4	29.2	037.9	11.0	3.5	11	09	21.2
66	232.2	44.1	049.7	06.5	4.2	11	16	07.2
67	224.0	42.5	007.7	12.5	3.2	14	13	02.8
68	191.6	44.1	268.8	13.0	4.2	08	17	08.3

TABLE D2

VARIABLES All recorded during the first five minutes of the session.

01 Mean basal conductance level. Session Two (BC2)

02 Number of galvanic skin responses. Session Two (No.GSR2)

03 Mean conductance change. Session Two (MCC2)

04 Mean integrated electromyogram level recorded from forehead. Session Two (EMG1.2)

05 Mean integrated electromyogram level recorded from neck. Session Two (EMG2.2)

06 Mean integrated electromyogram level recorded from upper arm. Session Two (EMG3.2)

07 Mean heart rate. Session Two (HR2)

08 Mean respiration rate. Session Two (RR2)

09 Mean inspiration/respiration ratio. Session Two (I/R2)

10 Mean eyeblink rate. Session One (EBR1)

TABLE D2 Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08	09	10
01	08826.0	06	0181.6	05.0	08.0	03.0	072.0	17.0	39	24.5
02	07567.0	02	0214.5	04.0	13.0	17.0	081.5	22.6	42	12.0
03	03531.0	04	0125.0	05.0	07.0	06.0	068.2	12.0	36	05.5
04	05051.0	11	0363.3	10.0	08.0	07.5	067.0	14.0	35	21.0
05	07816.0	10	0528.3	04.5	05.0	17.0	076.0	12.8	35	11.0
06	04544.0	32	0365.4	03.0	07.5	18.0	095.0	13.2	45	10.0
07	08185.0	13	0641.6	04.0	05.5	15.0	086.0	16.4	39	18.0
08	07369.0	10	0169.2	04.0	10.0	15.0	088.0	13.6	36	21.5
09	07367.0	26	0371.7	16.0	34.0	40.0	076.0	19.8	38	34.5
10	07258.0	02	0237.0	07.0	14.0	16.0	085.0	21.4	41	32.0
11	06213.0	11	0232.4	03.0	22.0	16.0	077.5	11.6	40	08.0
12	12470.0	37	1038.0	02.0	15.0	07.5	070.4	19.0	37	09.0
13	07449.0	04	0118.1	11.0	20.0	30.0	079.2	18.8	44	07.5
14	03345.0	01	0011.3	10.0	12.0	36.0	065.0	12.0	34	10.5
15	08770.0	26	0519.1	26.0	44.0	20.0	080.0	18.2	43	09.5
16	11876.0	00	0000.0	20.0	40.0	30.0	071.5	16.6	41	16.0
17	12183.0	18	0794.0	10.0	22.0	30.0	069.2	11.5	18	18.0
18	04246.0	32	0167.9	10.0	15.0	17.0	075.0	12.8	46	27.5
19	06874.0	27	0380.4	04.0	14.0	08.5	079.6	17.8	44	16.5
20	07466.0	01	0120.2	05.0	06.0	09.0	072.0	14.6	30	10.0
21	08534.0	38	0479.5	07.5	12.0	17.5	071,8	15,2	41	22.0
22	06928.0	00	0000.0	18.0	17.0	27.0	093.6	16.6	42	19.0
23	06625.0	17	0375.1	09.0	13.0	11.0	084.0	17.8	45	01.0
24	02329.0	01	0125.0	10.0	24.0	13.0	059.2	12.6	39	05.0
25	03963.0	05	0063.8	13.0	15.0	33.0	088.0	12.6	43	23.5
26	03328.0	05	0158.5	08.5	17.5	17.5	071.2	21.4	39	09.0
27	05286.0	07	0216.3	10.0	12.5	15.0	072.2	17.0	26	10.3
28	07689.0	26	0286.9	09.0	10.0	13.0	078.2	16.2	38	09.0
29	03409.0	04	0081.4	03.0	11.0	12.0	085.0	15.4	39	17.2
30	02991.0	17	0057.1	06.0	09.5	10.0	075.6	12.0	40	16.0
31	04431.0	10	0146.3	07.0	17.0	07.0	051.4	13.8	34	26.8
32	00888.8	00	0000.0	32.0	16.0	20.0	055.6	14.6	41	21.4
33	02299.0	04	0037.8	24.0	24.0	16.0	073.6	17.2	36	24.6
34	03533.0	27	0104.0	32.0	36.0	25.0	073.2	15.2	46	24.0

TABLE D2 cont. Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08	09	10
35	02538.0	00	0000.0	15.0	28.0	15.0	110.4	18.6	42	25.0
36	05039.0	01	0037.2	10.0	09.0	12.0	111.2	21.0	39	09.0
37	02249.0	19	0031.8	10.0	11.0	20.0	073.2	15.6	31	36.4
38	04042.0	28	0196.7	03.0	14.5	16.0	071.4	22.0	34	08.2
39	14672.0	07	1006.0	10.0	10.0	32.0	075.0	16.2	37	08.2
40	08188.0	02	0226.3	04.0	26.5	05.5	076.0	14.6	33	07.0
41	09105.0	07	0454.0	05.5	12.5	12.0	072.4	13.4	41	15.6
42	03001.0	10	0009.5	14.0	11.0	15.0	058.0	14.8	37	03.0
43	12325.0	19	1200.0	04.0	30.0	27.0	083.6	13.4	39	13.2
44	06161.0	13	0321.6	20.0	20.0	39.0	074.0	19.0	27	38.6
45	33373.0	25	1711.0	12.0	12.5	11.0	089.6	16.4	39	19.8
46	23059.0	07	0407.9	08.0	29.0	18.0	088.0	15.4	36	11.0
47	12810.0	09	0471.8	04.5	08.0	11.0	076.2	13.6	38	24.2
48	02367.0	01	0037.1	07.5	24.5	15.0	061.0	12.8	30	31.0
49	15940.0	04	2220.0	21.0	30.0	36.0	071.4	17.6	38	42.8
50	04797.0	04	0073.4	08.0	20.0	13.0	058.2	16.8	36	04.6
51	06066.0	26	0154.3	10.5	11.5	10.0	100.0	21.2	35	02.2
52	11600.0	04	0194.6	16.0	19.0	28.0	087.2	16.8	39	09.0
53	04385.0	00	0000.0	15.0	25.0	16.0	071.8	15.0	37	14.4
54	17060.0	05	0568.6	18.0	26.0	20.0	076.6	18.0	35	22.0
55	02465.0	01	0020.4	12.0	18,0	16.0	060.2	15.6	31	12.0
56	05199.0	33	0752.4	08.0	26.0	20.0	071.6	17.2	36	11.8
57	04744.0	36	0335.8	22.0	20.0	22.0	091.0	12.8	44	17.4
58	02371.0	05	0036.7	10.0	11.0	09.0	073.2	19.8	33	10.6
59	07369.0	10	0161.5	04.0	05.5	06.5	063.6	18.6	34	10.2
60	03789.0	01	0044.4	10.0	21.0	22.0	070.2	13.6	37	06.8
61	03560.0	03	0049.6	24.0	30.0	20.0	059.8	12.4	33	05.6
62	05241.0	01	0343.5	14.0	32.0	26.0	066.0	09.6	41	06.8
63	04207.0	10	0059.9	10.0	34.0	16.0	073.0	14.6	36	07.6
64	03092.0	06	0073.4	20.0	23.0	15.0	081.4	19.6	35	06.6
65	03545.0	04	0020.8	28.0	35.0	30.0	061.6	12.6	33	13.2
66	04204.0	02	0337.3	06.5	14.0	12.0	070.6	11.8	38	04.6
67	02186.0	00	0000.0	12.0	12.0	20.0	072.6	10.0	27	12.8
68	05533.0	05	0238.8	08.0	21.0	15.0	077.2	16.2	40	11.8

TABLE D3

VARIABLES All recorded during the first five minutes of the session.

01 Mean basal conductance level. Session Three (BC3)

02 Number of galvanic skin responses. Session Three (No.GSR3)

03 Mean conductance change. Session Three (MCC3)

04 Mean integrated electromyogram level recorded from forehead. Session Three (EMG1.3)

05 Mean integrated electromyogram level recorded from neck. Session Three (EMG2.3)

06 Mean integrated electromyogram level recorded from upper arm. Session Three (EMG3.3)

07 Mean heart rate. Session Three (HR3)

08 Mean respiration rate. Session One (RR1)

09 Mean inspiration/respiration ratio. Session One I/R1)

10 Mean eyeblink rate. Session Three (EBR3)

TABLE D3 Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08	09	10
01	08772.0	00	0000.0	02.5	06.0	03.0	072.0	17.0	39	32.8
02	08931.0	06	0280.6	04.5	04.0	15.5	087.0	20.8	45	23.0
03	02540.0	18	0050.8	04.0	13.0	04.0	072.0	09.8	41	03.2
04	03280.0	04	0401.1	09.5	11.0	06.5	078.0	14.2	38	26.0
05	09173.0	05	0203.0	03.5	08.0	15.0	077.0	11.2	33	11.0
06	07472.0	16	0314.0	04.5	07.0	10.0	094.6	20.0	44	11.0
07	07422.0	13	0232.7	03.5	07.0	11.5	083.0	15.4	46	16.0
08	04984.0	04	0067.5	03.5	09.0	11.0	076.0	13.5	36	14.0
09	06133.0	38	0468.2	08.0	14.0	32.0	076.0	17.2	32	22.0
10	09528.0	02	0366.4	01.5	04.0	04.0	088.0	20.5	41	18.0
11	08098.0	11	0541.1	11.0	30.0	29.0	083.0	11.2	42	13.8
12	08772.0	35	0563.4	04.0	07.5	08.5	069.8	22.5	39	10.0
13	04322.0	06	0041.7	14.0	24.0	20;0	075.0	18.6	43	12.0
14	06905.0	24	0335.1	18.0	09.0	40.0	063.0	11.2	33	13.0
15	09534.0	27	0713.0	12.5	23.0	19.0	084.0	15.2	43	10.6
16	03654.0	01	0027.9	14.0	23.0	15.0	077.8	18.8	45	10.0
17	05438.0	01	0153.5	24.0	26.0	30.0	065.0	14.0	38	14.4
18	03877.0	27	0126.7	08.0	26.0	13.0	071.3	14.2	48	19.8
19	05264.0	29	0221.4	12.0	15.0	11.0	076.0	15.4	39	22.8
20	02014.0	01	0104.6	08.0	03.0	10.0	077.0	14.6	36	36.8
21	06286.0	31	0609.1	10.0	30.0	09.0	071.0	17.4	46	22.8
22	05436.0	04	0120.1	20.0	03.0	36.0	093.0	15.6	39	21.5
23	05352.0	27	0340.3	16.0	12.0	17.0	105.8	14.8	46	02.4
24	05272.0	15	0319.5	10.0	20.0	12.0	061.3	13.8	46	09.0
25	05022.0	04	0051.2	06.0	16.0	26.0	089.0	15.4	36	22.8
26	03214.0	02	0156.0	10.0	20.0	15.0	068.0	22.6	31	05.6
27	04684.0	03	0265.4	11.0	19.0	10.0	072.8	15.8	35	03.6
28	03332.0	14	0274.7	03.0	10.0	08.0	075.0	16.0	39	11.4
29	04449.0	23	0313.4	02.0	11.0	10.0	079.3	20.6	40	26.9
30	00630.8	00	0000.0	10.0	12.0	06.0	073.6	13.6	42	15.6
31	05202.0	25	0256.0	05.0	16.0	08.0	060.0	15.6	34	33.0
32	00708.6	00	0000.0	16.0	32.0	40.0	060.0	16.0	41	25.6
33	07121.0	24	0482.2	06.0	14.0	15.0	079.8	17.0	35	14.4
34	05128.0	28	0205.2	20.0	14.0	12.0	078.2	17.6	45	32.6

TABLE D3 cont.

SUBJECT IDENTIFICATION	Variables 01	02	03	04	05	06	07	08	09	10
35	02959.0	00	0000.0	06.0	16.5	16.0	084.8	19.6	44	52.8
36	04650.0	02	0040.4	06.0	05.0	08.0	081.0	19.4	42	10.0
37	03010.0	19	0056.7	18.0	26.0	25.0	072.0	16.2	35	12.3
38	04273.0	12	0104.8	01.0	25.0	01.5	067.4	20.8	37	02.3
39	14380.0	15	1235.0	03.0	08.0	10.0	070.5	17.2	35	10.8
40	07328.0	04	0157.3	04.0	15.0	12.5	079.8	14.8	33	05.4
41	10120.0	06	0809.1	08.0	14.0	12.0	064.6	17.0	38	19.8
42	03961.0	01	0231.7	07.0	11.0	20.0	065.6	14.4	38	01.5
43	12300.0	26	0729.4	22.0	20.0	08.0	090.2	12.2	42	17.8
44	11010.0	01	0510.5	14.0	20.0	26.0	068.4	18.2	32	13.0
45	19550.0	19	0789.3	05.0	07.0	04.0	087.6	17.6	39	18.4
46	19390.0	08	1658.0	10.0	15.0	36.0	080.2	13.8	39	10.6
47	10440.0	15	0481.4	10.0	20.0	28.0	072.2	20.0	40	17.4
48	02238.0	00	0000.0	07.0	16.0	13.0	060.4	13.4	40	24.6
49	10050.0	23	0380.4	10.0	18.0	20.0	079.0	18.0	34	46.2
50	06294.0	10	0248.7	08.0	14.0	14.0	050.2	09.6	47	07.4
51	08338.0	03	0419.1	12.0	12.0	12.0	099.0	17.4	40	02.6
52	12040.0	21	0219.9	14.0	18.0	14.0	081.0	17.2	39	12.0
53	06933.0	02	0359.4	04.0	11.0	05.0	066.4	16.0	41	07.2
54	06608.0	08	0258.5	10.0	15.0	05.0	072.2	14.4	31	17.0
55	04012.0	11	0660.8	24.0	16.0	17.0	058.0	16.0	37	12.6
56	07678.0	31	0926.1	14.0	08.0	28.0	073.8	17.0	41	14.4
57	06580.0	38	0779.4	20.0	16.0	14.0	083.0	21.2	38	19.8
58	07169.0	11	0578.2	10.0	12.0	10.0	084.0	19.2	32	13.4
59	07124.0	12	0221.8	07.0	05.0	07.5	064.6	18.6	36	16.6
60	04489.0	03	0151.8	06.0	07.0	02.5	075.2	15.4	35	04.0
61	02602.0	12	0109.2	24.0	26.0	22.0	059.2	16.0	38	09.8
62	07713.0	30	0350.6	10.0	14.0	10.0	077.6	10.4	38	02.8
63	03668.0	15	0050.7	24.0	32.0	60.0	071.6	19.0	45	07.0
64	01808.0	11	0018.6	14.0	10.0	06.0	074.6	18.0	34	06.2
65	02497.0	14	0089.5	24.0	26.0	20.0	062.0	13.2	38	12.8
66	04092.0	07	0166.8	05.0	05.0	10.0	076.4	11.2	37	05.2
67	01763.0	00	0000.0	09.0	06.0	17.0	073.2	11.4	36	27.4
68	03584.0	02	0230.3	02.0	02.0	03.0	071.8	14.4	34	20.0

TABLE D4

VARIABLES All variables recorded in Session One.

01 Mean basal conductance level during first five minutes (BC1).

02 Number of galvanic skin responses during first five minutes (No.GSR1).

03 Mean conductance change during first five minutes (MCC1).

04 Mean respiration rate during first five minutes (RR1).

05 Mean inspiration/respiration ratio during first five minutes (I/R1).

06 Mean eyeblink rate during first five minutes (EBR1).

07 Mean figure reversal rate (first period) ($FRR1_1$).

08 Threshold score (Reversed Threshold Score).

TABLE D4

SUBJECT IDENTIFICATION	Variables 01	02	03	04	05	06	07	08
01	04854	00	000.00	17.0	39	24.5	08.5	3.5
02	11364	00	000.00	20.8	45	12.0	13.0	3.0
03	03209	11	160.00	09.8	41	05.5	05.0	3.3
04	04763	08	418.20	14.2	38	21.0	15.0	3.7
05	05485	07	124.90	11.2	33	11.0	05.5	3.5
06	07047	16	608.60	20.0	44	10.0	23.5	3.7
07	08253	11	630.00	15.4	46	18.0	14.5	4.0
08	05431	20	177.40	13.5	36	21.5	08.5	3.5
09	04183	28	319.20	17.2	32	34.5	08.0	3.8
10	05360	25	533.30	20.5	41	32.0	20.5	3.3
11	06475	15	329.00	11.2	42	08.0	15.0	3.0
12	06249	36	303.20	22.5	39	09.0	10.0	4.5
13	05253	11	142.40	18.6	43	07.5	34.0	4.7
14	05099	00	000.00	11.2	33	10.5	12.0	2.5
15	06390	27	403.10	15.2	43	09.5	10.5	4.0
16	10516	02	326.50	18.8	45	16.0	12.0	2.8
17	05261	14	111.40	14.0	38	18.0	14.0	3.3
18	02557	23	083.67	14.2	48	27.5	09.0	4.0
19	05022	15	287.30	15.4	39	16.5	07.0	4.2
20	05228	02	084.90	14.6	36	10.0	20.0	3.2
21	05365	26	361.70	17.4	46	22.0	07.0	4.5
22	03398	01	208.70	15.6	39	19.0	14.5	3.5
23	03585	22	076.29	14.8	46	01.0	09.0	2.8
24	04144	15	217.40	13.8	46	05.0	13.5	3.8
25	04191	06	201.40	15.4	36	23.5	11.5	3.3
26	05749	03	097.46	22.6	31	09.0	22.5	3.5
27	06856	06	348.80	15.8	35	10.3	24.0	3.3
28	04263	38	271.10	16.0	39	09.0	24.5	4.3
29	02806	33	142.60	20.6	40	17.2	08.5	4.3
30	02789	25	126.30	13.6	42	16.0	01.0	5.0
31	08242	18	444.80	15.6	34	26.8	11.5	3.0
32	01020	06	048.13	16.0	41	21.4	14.5	4.7
33	02752	18	039.12	17.0	35	24.6	13.5	4.5
34	02519	23	071.19	17.6	45	24.0	09.0	4.7

TABLE D4 cont. Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08
35	03278	02	035.80	19.6	44	25.0	17.0	6.0
36	03824	02	047.05	19.4	42	09.0	19.5	3.0
37	02537	32	062.87	16.2	35	36.4	16.5	3.7
38	01988	32	047.68	20.8	37	08.2	13.5	6.0
39	09685	00	000.00	17.2	35	08.2	22.0	2.5
40	05060	08	524.90	14.8	33	07.0	05.5	3.5
41	06858	12	942.30	17.0	38	15.6	24.0	2.7
42	08819	44	572.90	14.4	38	03.0	24.5	2.7
43	07896	39	601.30	12.2	42	13.2	13.5	3.2
44	05373	17	306.30	18.2	32	38.6	08.0	3.0
45	10250	45	192.80	17.6	39	19.8	15.0	3.3
46	10890	26	235.20	13.8	39	11.0	22.0	2.7
47	08712	20	322.50	20.0	40	24.2	06.0	2.3
48	02628	02	074.71	13.4	40	31.0	10.0	3.8
49	07316	34	395.70	18.0	34	42.8	23.0	3.0
50	03490	07	206.10	09.6	47	04.6	14.0	2.8
51	03452	09	133.60	17.4	40	02.2	14.5	3.2
52	11730	03	141.30	17.2	39	09.0	41.5	1.5
53	03756	06	158.00	16.0	41	14.4	09.0	4.7
54	08881	11	422.30	14.4	31	22.0	12.5	4.0
55	02705	10	139.90	16.0	37	12.0	13.0	2.7
56	05276	31	665.60	17.0	41	11.8	16.0	3.2
57	05867	44	448.70	21.2	38	17.4	08.5	2.3
58	01568	02	154.90	19.2	32	10.6	07.5	2.3
59	09656	22	493.00	18.6	36	10.2	14.0	2.3
60	04886	04	082.33	15.4	35	06.8	15.5	2.3
61	03233	03	085.36	16.0	38	05.6	13.5	3.5
62	04710	16	119.60	10.4	38	06.8	24.0	3.3
63	03795	09	047.61	19.0	45	07.6	20.0	3.0
64	02636	07	035.50	18.0	34	06.6	21.5	2.5
65	01582	00	000.00	13.2	38	13.2	20.5	3.5
66	03693	11	154.90	11.2	37	04.6	07.0	4.2
67	01746	01	005.82	11.4	36	12.8	02.0	3.2
68	03529	12	067.65	14.4	34	11.8	07.5	4.2

TABLE D5

VARIABLES All recorded in Session One.

01 Mean basal conductance level two minutes post learning (BCPL).

02 Number of galvanic skin responses two minutes post learning (No.GSRPL).

03 Mean conductance change two minutes post learning (MCCPL).

04 Mean respiration rate two minutes post learning (RRPL).

05 Mean inspiration/respiration ratio two minutes post learning (I/RPL).

06 Mean eyeblink rate during first five minutes (EBR1).

07 Mean figure reversal rate (first period) ($FRR1_1$).

08 N scale scores (N Score).

09 E scale scores (E Score).

10 Word recall score (Recall Score).

TABLE D5

Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08	09	10
01	07284	05	0058.2	17.5	41	24.5	08.5	15	10	09.5
02	17150	02	0303.8	22.0	42	12.0	13.0	10	13	21.0
03	05000	00	0000.0	16.0	31	05.5	05.0	02	13	17.0
04	07372	09	0260.4	16.5	37	21.0	15.0	03	11	27.0
05	07251	09	0148.9	12.5	32	11.0	05.5	08	11	10.5
06	08622	06	0359.3	19.5	46	10.0	23.5	11	12	13.0
07	12670	19	0296.1	14.5	45	18.0	14.5	04	07	25.0
08	06732	19	0193.9	15.0	36	21.5	08.5	07	17	09.0
09	07076	13	0659.7	17.0	35	34.5	08.0	02	16	15.5
10	10234	02	0646.2	24.0	40	32.0	20.5	12	14	18.0
11	09158	22	0206.9	15.0	35	08.0	15.0	07	14	19.0
12	10497	19	0559.4	22.5	38	09.0	10.0	07	13	06.0
13	11195	04	0383.1	21.0	45	07.5	34.0	13	17	11.0
14	06568	05	0112.1	11.5	34	10.5	12.0	03	05	25.0
15	11371	09	0485.4	11.5	39	09.5	10.5	06	12	12.0
16	14288	00	0000.0	14.0	40	16.0	12.0	04	11	16.0
17	10723	06	0310.8	10.5	38	18.0	14.0	05	18	22.0
18	04072	08	0093.7	11.5	50	27.5	09.0	17	15	07.0
19	09151	13	0344.0	16.0	43	16.5	07.0	10	10	16.0
20	09874	03	0338.7	13.0	42	10.0	20.0	12	13	10.0
21	08808	07	0490.7	14.5	41	22.0	07.0	13	16	06.5
22	05630	03	0052.4	18.0	41	19.0	14.5	06	19	12.0
23	05002	15	0222.2	14.0	39	01.0	09.0	08	14	25.0
24	07500	03	0185.6	13.5	40	05.0	13.5	15	16	14.0
25	05831	08	0165.5	14.5	40	23.5	11.5	12	15	07.0
26	09212	03	0560.0	21.5	29	09.0	22.5	07	16	07.0
27	13520	03	0467.3	15.5	33	10.3	24.0	15	11	19.0
28	07740	16	1121.0	16.0	31	09.0	24.5	16	19	06.0
29	03944	11	0299.3	19.0	35	17.2	08.5	07	20	16.0
30	05877	23	0393.3	16.0	37	16.0	01.0	14	11	09.0
31	07464	14	0614.4	14.5	34	26.8	11.5	14	09	06.0
32	02805	04	0417.2	16.0	36	21.4	14.5	05	18	17.0
33	04918	08	0358.6	17.0	21	24.6	13.5	08	13	15.0
34	03478	08	0090.0	20.0	45	24.0	09.0	12	18	08.5

TABLE D5 cont.

SUBJECT IDENTIFICATION	Variables 01	02	03	04	05	06	07	08	09	10
35	06554	02	0264.8	18.5	36	25.0	17.0	13	13	05.0
36	03944	03	0082.9	15.0	40	09.0	19.5	09	06	15.0
37	03044	05	0107.2	14.5	40	36.4	16.5	07	12	04.0
38	03629	04	0140.7	20.0	31	08.2	13.5	14	08	14.0
39	12714	08	0530.4	17.5	27	08.2	22.0	03	15	22.0
40	07434	03	0575.9	15.5	38	07.0	05.5	07	06	11.5
41	10867	11	1142.0	12.5	35	15.6	24.0	07	14	18.5
42	11467	13	0996.3	11.0	37	03.0	24.5	16	07	13.5
43	17229	28	1207.0	12.5	35	13.2	13.5	11	16	15.0
44	07410	14	0179.2	22.0	31	38.6	08.0	09	17	17.0
45	15555	13	0225.7	15.5	37	19.8	15.0	10	03	25.5
46	17576	10	0919.3	15.5	37	11.0	22.0	06	13	10.0
47	11600	19	0412.0	20.0	36	24.2	06.0	10	15	14.0
48	04446	10	0216.8	16.0	34	31.0	10.0	08	14	18.5
49	10400	16	0466.1	15.0	29	42.8	23.0	10	12	14.0
50	06357	12	0792.0	07.0	36	04.6	14.0	07	11	07.0
51	06948	10	0205.7	19.0	40	02.2	14.5	08	12	14.0
52	17443	04	0336.2	14.5	37	09.0	41.5	07	15	16.5
53	06302	03	0601.4	16.0	39	14.4	09.0	07	11	14.0
54	15710	06	0345.2	19.5	38	22.0	12.5	11	07	18.5
55	06160	02	0500.0	16.5	34	12.0	13.0	15	16	06.0
56	07051	07	0564.8	14.5	38	11.8	16.0	16	19	07.0
57	11935	22	0783.5	13.0	41	17.4	08.5	18	16	04.0
58	02329	00	0000.0	19.5	31	10.6	07.5	15	16	07.0
59	13710	12	0872.8	21.5	38	10.2	14.0	13	13	08.0
60	06304	02	0612.0	16.5	32	06.8	15.5	11	17	09.5
61	04323	05	0231.8	14.0	42	05.6	13.5	12	20	12.0
62	08889	04	0171.2	11.5	33	06.8	24.0	07	11	09.0
63	06357	03	0066.2	15.0	36	07.6	20.0	09	10	19.0
64	04031	03	0113.4	18.5	39	06.6	21.5	07	17	18.0
65	04696	04	0208.2	14.0	34	13.2	20.5	11	09	11.0
66	04633	07	0205.7	13.0	39	04.6	07.0	11	16	06.5
67	02699	03	0027.2	12.0	39	12.8	02.0	14	13	12.5
68	07237	04	0654.3	13.5	31	11.8	07.5	08	17	13.0

TABLE D6

VARIABLES All recorded in Session One.

01 Mean basal conductance level two minutes post recall (BCPRcl).

02 Number of galvanic skin responses two minutes post recall (No.GSRPRcl).

03 Mean conductance change two minutes post recall (MCCPRcl).

04 Mean respiration rate two minutes post recall (RRPRcl).

05 Mean inspiration/respiration ratio two minutes post recall (I/RPRcl).

06 Mean eyeblink rate during first five minutes (EBR1).

07 Mean figure reversal rate (second period) ($FRR1_2$).

08 N scale scores (N Score).

09 E scale scores (E Score).

10 Word recall scores (Recall Score).

TABLE D6

Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08	09	10
01	08175	04	0076.2	16.5	38	24.5	15.0	15	10	09.5
02	19300	01	0362.8	21.0	43	12.0	28.5	10	13	21.0
03	05164	00	0000.0	15.5	42	05.5	08.5	02	13	17.0
04	07792	03	0232.0	14.0	45	21.0	18.5	03	11	27.0
05	07581	01	0051.8	12.5	38	11.0	09.0	08	11	10.5
06	09588	08	0337.7	15.0	47	10.0	18.0	11	12	13.0
07	12772	08	0261.8	13.5	40	18.0	16.0	04	07	25.0
08	07077	12	0231.7	14.0	37	21.5	13.0	07	17	09.0
09	08064	13	0502.1	21.5	38	34.5	22.5	02	16	15.5
10	11831	06	1317.0	21.5	40	32.0	25.0	12	14	18.0
11	10174	06	0331.1	15.0	38	08.0	14.5	07	14	19.0
12	12933	19	0524.4	21.0	36	09.0	10.0	07	13	06.0
13	11191	01	0564.7	18.5	42	07.5	21.5	13	17	11.0
14	08475	07	0132.7	10.0	30	10.5	16.0	03	05	25.0
15	10170	10	0526.1	15.0	40	09.5	08.5	06	12	12.0
16	11768	00	0000.0	15.5	39	16.0	09.5	04	11	16.0
17	10634	09	0265.2	12.0	29	18.0	23.0	05	18	22.0
18	04107	06	0223.0	14.0	48	27.5	09.0	17	15	07.0
19	09945	08	0152.1	18.5	41	16.5	03.5	10	10	16.0
20	10681	05	0381.7	15.5	32	10.0	19.5	12	13	10.0
21	09837	11	0452.1	13.0	40	22.0	04.0	13	16	06.5
22	08159	02	0877.7	16.0	44	19.0	13.5	06	19	12.0
23	05440	14	0196.1	14.0	35	01.0	09.0	08	14	25.0
24	06960	08	0547.1	12.5	33	05.0	09.0	15	16	14.0
25	06151	13	0359.1	12.5	42	23.5	05.0	12	15	07.0
26	07292	02	0735.7	22.5	34	09.0	21.0	07	16	07.0
27	15881	03	0896.5	15.0	29	10.3	15.5	15	11	19.0
28	08746	10	0784.8	16.0	38	09.0	27.5	16	19	06.0
29	04096	08	0320.3	20.5	33	17.2	10.0	07	20	16.0
30	05417	22	0228.7	16.0	42	16.0	01.0	14	11	09.0
31	07624	19	0317.0	15.0	34	26.8	06.0	14	09	06.0
32	01691	10	0112.0	15.5	32	21.4	19.5	05	18	17.0
33	05214	09	0471.4	17.5	37	24.6	20.5	08	13	15.0
34	04011	08	0134.0	17.0	47	24.0	09.5	12	18	08.5

TABLE D6 cont. Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08	09	10
35	06717	02	0463.1	19.5	40	25.0	14.0	13	13	05.0
36	06849	02	0225.9	16.0	35	09.0	19.5	09	06	15.0
37	03477	10	0116.1	15.0	39	36.4	19.5	07	12	04.0
38	04714	10	0223.1	21.5	34	08.2	13.0	14	08	14.0
39	16087	05	1353.0	16.5	32	08.2	15.5	03	15	22.0
40	06826	06	0429.0	14.0	42	07.0	02.5	07	06	11.5
41	12964	06	1521.0	13.0	31	15.6	23.5	07	14	18.5
42	13769	08	0751.5	14.0	36	03.0	21.0	16	07	13.5
43	19847	22	1477.0	13.5	32	13.2	14.0	11	16	15.0
44	08250	12	0227.0	21.0	31	38.6	07.5	09	17	17.0
45	17005	14	0248.0	14.0	31	19.8	13.0	10	03	25.5
46	17667	11	1138.0	11.5	37	11.0	32.5	06	13	10.0
47	14061	23	0571.5	18.0	33	24.2	07.5	10	15	14.0
48	05064	05	0050.1	14.0	34	31.0	11.0	08	14	18.5
49	11996	06	0978.2	16.0	29	42.8	37.5	10	12	14.0
50	06017	00	0000.0	10.0	37	04.6	16.5	07	11	07.0
51	08117	07	0247.9	20.0	41	02.2	14.0	08	12	14.0
52	19869	06	0359.8	14.0	35	09.0	55.5	07	15	16.5
53	06987	16	0240.0	15.0	29	14.4	10.5	07	11	14.0
54	17164	05	0465.7	13.0	28	22.0	11.5	11	07	18.5
55	05746	07	0552.6	15.5	34	12.0	11.0	15	16	06.0
56	07635	13	0938.0	17.0	39	11.8	20.0	16	19	07.0
57	14568	18	1461.0	10.5	35	17.4	09.0	18	16	04.0
58	03677	04	0253.8	15.5	34	10.6	06.5	15	16	07.0
59	20064	21	2455.0	21.5	38	10.2	14.0	13	13	08.0
60	08164	01	1070.0	16.5	30	06.8	25.0	11	17	09.5
61	03871	03	0176.1	14.0	37	05.6	08.5	12	20	12.0
62	10639	05	0307.5	08.0	43	06.8	21.0	07	11	09.0
63	07752	00	0000.0	13.5	32	07.6	20.0	09	10	19.0
64	05428	03	0113.1	17.0	34	06.6	15.0	07	17	18.0
65	05683	05	0216.0	13.0	33	13.2	21.5	11	09	11.0
66	04486	04	0123.2	11.0	44	04.6	07.0	11	16	06.5
67	03642	03	0158.9	14.5	37	12.8	01.5	14	13	12.5
68	05317	01	0446.2	12.5	29	11.8	07.5	08	17	13.0

TABLE D7

VARIABLES

01 Mean basal conductance level during reaction time task (BCRT).

02 Number of galvanic skin responses to the warning light (No.GSRWL).

03 Mean conductance change to the warning light (MCCRT).

04 Mean respiration rate in twenty second period after S told of RT task (RRRT).

05 Mean inspiration/respiration ratio in twenty second period after S told of RT task (I/RRT).

06 Mean heart rate in twenty second period after S told of RT task (HRRT).

07 Mean integrated electromyogram level recorded from forehead during RT task (EMG1RT).

08 Mean integrated electromyogram level recorded from neck during RT task (EMG2RT).

09 Mean integrated electromyogram level recorded from upper arm during RT task (EMG3RT).

10 Mean latency of galvanic skin response to the warning light (Mean latency).

11 Mean of the best ten reaction times (Best 10 RT).

TABLE D7

Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08	09	10	11
01	09647	15	0035.2	18	39	075	11.0	30.0	12.0	2.59	214.4
02	10400	33	0262.5	24	39	081	08.0	12.5	16.0	2.29	197.7
03	05078	41	0106.7	09	24	090	05.0	06.5	08.0	2.46	224.4
04	06433	50	0743.5	12	37	087	18.0	11.0	11.0	2.01	185.1
05	09900	44	0677.8	15	43	081	04.0	08.0	16.0	2.38	190.3
06	06156	47	0416.5	18	42	099	04.0	11.5	10.0	2.40	232.6
07	07868	44	0369.0	18	41	093	03.5	06.0	21.0	2.41	201.5
08	08226	46	0279.1	12	32	090	07.0	12.0	10.0	2.54	188.9
09	08989	46	0553.7	21	39	081	20.0	40.0	32.0	2.13	228.2
10	08570	42	0753.1	24	49	096	07.0	14.0	25.0	2.29	226.9
11	07787	24	0121.7	18	33	081	07.0	18.0	21.5	2.24	203.8
12	16540	42	0966.9	21	38	081	07.0	18.0	20.0	2.10	205.5
13	11480	30	0260.2	21	40	084	22.0	08.0	60.0	2.25	214.4
14	06592	24	0295.6	15	31	072	12.0	14.0	38.0	2.66	251.3
15	09376	39	0528.7	21	47	090	24.0	39.0	22.0	2.41	238.1
16	10430	36	0314.6	24	39	069	22.0	64.0	52.0	2.44	199.9
17	13690	20	0295.5	15	30	069	10.0	32.0	29.0	2.56	181.9
18	05076	46	0565.6	12	54	084	10.0	13.0	19.0	2.44	249.4
19	07914	48	0347.6	18	38	093	05.0	13.0	10.0	2.39	215.3
20	07536	42	0211.7	12	31	063	19.0	20.0	22.0	2.34	205.8
21	10270	34	0331.2	18	38	075	09.0	12.5	15.0	2.55	210.1
22	09915	19	0077.1	21	41	108	12.0	27.0	30.0	2.29	220.8
23	07055	50	0742.4	18	47	111	10.0	18.0	12.0	1.98	197.3
24	05403	50	0900.1	18	45	090	11.0	14.0	22.0	2.19	201.7
25	03524	31	0122.8	21	41	090	12.0	30.0	46.0	2.72	252.1
26	04846	44	1258.0	24	36	081	07.5	13.0	20.0	2.41	223.1
27	08590	33	0216.2	18	40	105	11.0	26.0	22.0	2.43	212.4
28	10540	26	0588.6	18	45	087	10.0	15.0	22.0	2.15	185.0
29	03683	39	0230.9	24	40	093	09.0	14.0	20.0	2.28	218.3
30	04039	49	0240.3	18	41	072	06.0	09.0	07.5	2.13	222.2
31	03477	38	0145.6	15	35	066	07.0	15.0	06.5	2.73	227.5
32	02167	38	0305.9	18	41	069	18.0	12.0	25.0	2.65	223.6
33	05693	37	0626.6	21	40	066	22.0	26.0	20.0	2.50	216.3
34	04162	44	0105.4	18	44	102	36.0	37.0	31.0	2.23	182.6

TABLE D7 cont.

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07	08	09	10	11
35	05533	21	0119.3	21	39	111	14.0	27.0	13.0	2.73	253.4
36	12170	28	0252.7	21	31	102	08.5	09.0	12.0	2.40	220.2
37	03455	39	0166.5	15	30	087	10.0	12.0	29.0	2.34	246.4
38	05842	38	0338.1	21	35	084	03.0	22.5	22.0	2.46	204.4
39	16350	23	0441.6	15	39	075	20.0	20.0	44.0	2.50	191.9
40	07285	38	0498.3	18	36	081	03.0	16.0	08.5	2.44	214.1
41	09861	47	0786.8	15	35	084	05.0	13.5	12.5	2.28	208.7
42	05735	38	0654.3	15	30	063	06.0	05.0	12.0	2.34	196.0
43	16420	47	1324.0	18	45	096	15.0	44.0	34.0	2.03	197.0
44	07675	14	0142.2	21	33	078	22.0	20.0	32.0	2.34	213.2
45	16401	05	0213.8	21	36	096	11.0	11.0	10.0	2.34	198.3
46	19395	33	0846.1	15	32	093	09.0	30.0	18.0	1.89	208.7
47	11400	34	0442.5	21	38	081	05.5	08.5	12.5	2.34	219.1
48	03721	06	0034.3	15	38	066	26.0	30.0	31.0	2.85	205.0
49	11930	18	0294.7	15	36	075	20.0	34.0	26.0	2.38	234.8
50	07347	39	0288.9	18	39	102	09.0	15.5	19.0	2.10	201.5
51	09239	09	0036.5	21	41	099	19.0	19.0	17.0	2.13	205.5
52	14531	13	0029.8	18	40	117	11.0	19.0	25.0	1.96	197.0
53	06225	34	0112.3	21	37	090	14.0	22.0	27.0	2.43	233.9
54	19901	38	0344.7	21	43	072	16.0	24.0	15.0	2.00	223.4
55	03937	26	0120.3	18	34	066	12.0	16.0	17.0	2.60	226.4
56	06296	33	0550.3	18	39	072	14.0	19.0	20.0	2.71	238.1
57	06192	36	0315.5	12	45	108	22.0	14.0	19.5	2.48	215.2
58	03942	20	0161.7	18	37	078	06.0	16.0	11.0	2.60	197.2
59	10966	40	0401.0	18	43	075	10.0	12.0	15.5	2.45	214.8
60	05678	10	0027.8	21	43	087	11.0	19.0	18.0	2.34	206.0
61	03279	26	0087.7	15	34	063	12.0	34.0	20.0	3.13	235.3
62	05602	35	0098.4	09	50	087	14.0	26.0	28.0	2.68	220.8
63	05665	25	0017.3	15	34	093	13.0	21.0	18.0	2.50	230.8
64	05413	17	0027.1	21	39	084	24.0	28.0	27.0	2.51	206.0
65	05765	37	0148.2	15	42	072	26.0	50.0	60.0	2.47	226.4
66	03620	35	0100.0	15	42	084	10.0	12.0	15.0	2.94	232.2
67	06479	11	0086.0	18	42	084	14.0	13.0	29.0	2.62	224.0
68	07936	17	0120.6	18	40	078	09.0	24.0	16.0	2.69	191.6

TABLE D8

VARIABLES

01 Mean basal conductance level during pursuit rotor tracking (BCT).

02 Heart rate in twenty second period after S told of tracking task (HR(T)).

03 Mean integrated electromyogram level recorded from forehead during tracking (EMG1(T)).

04 Mean integrated electromyogram level recorded from neck during tracking (EMG2(T)).

05 Mean integrated electromyogram level recorded from upper arm during tracking (EMG3(T)).

06 N Scale scores (N Score).

07 Pursuit rotor tracking. Time on target (Tracking Score).

TABLE D8

Variables

SUBJECT IDENTIFICATION	01	02	03	04	05	06	07
01	10433	078	03.0	06.0	13.0	15	065.3
02	13400	081	04.5	04.5	08.0	10	141.2
03	05118	072	06.5	18.0	04.0	02	138.8
04	06283	081	07.0	06.0	18.0	03	229.6
05	06347	084	05.0	09.0	14.5	08	148.4
06	06926	093	04.5	08.5	10.0	11	036.3
07	09745	099	04.0	08.0	12.0	04	162.4
08	05537	090	04.0	13.0	15.5	07	160.6
09	09575	081	09.0	24.0	32.0	02	042.5
10	06994	084	02.5	04.0	05.0	12	018.3
11	10439	090	09.0	28.0	24.0	07	126.9
12	13084	081	04.0	12.0	22.0	07	034.5
13	06880	081	13.0	27.0	19.5	13	038.4
14	08883	069	15.0	09.0	40.0	03	056.3
15	10932	090	11.5	16.5	19.5	06	064.7
16	06531	075	13.0	51.0	10.0	04	072.8
17	08151	057	09.0	26.0	26.0	05	250.7
18	04820	072	03.0	25.0	35.0	17	030.7
19	06061	075	07.0	12.0	09.0	10	064.7
20	05126	066	11.0	12.0	11.0	12	043.4
21	08937	063	11.0	34.0	16.0	13	025.7
22	07437	090	11.0	22.0	19.0	06	004.2
23	07064	123	18.0	13.0	29.0	08	174.2
24	06059	063	13.0	24.0	14.0	15	158.4
25	05172	084	09.0	18.0	35.0	12	003.9
26	05712	072	10.0	20.0	22.0	07	044.9
27	07948	078	12.0	20.0	16.0	15	014.5
28	04267	078	09.0	22.0	20.0	16	157.0
29	05318	087	09.0	17.0	20.0	07	022.0
30	04824	069	10.0	15.0	08.0	14	070.1
31	04341	060	05.0	12.5	10.5	14	063.8
32	02270	057	26.0	38.0	34.0	05	044.9
33	10809	075	03.0	13.0	16.5	08	111.4
34	05245	078	34.0	30.0	20.0	12	080.4

TABLE D8 cont.

SUBJECT IDENTIFICATION	Variables 01	02	03	04	05	06	07
35	05916	087	07.0	16.0	14.0	13	007.8
36	07634	078	10.0	12.0	16.0	09	175.3
37	04232	072	24.0	26.0	34.0	07	012.4
38	07092	063	09.0	34.0	14.0	14	143.9
39	15619	066	16.0	28.0	24.0	03	090.8
40	06010	096	04.0	18.0	19.0	07	052.5
41	07568	063	08.0	18.0	13.0	07	019.6
42	05197	063	10.0	14.0	25.0	15	053.9
43	11805	090	25.0	11.0	15.0	11	072.4
44	08200	066	20.0	26.0	36.0	09	003.4
45	19490	090	07.0	08.0	19.5	10	120.8
46	14842	093	10.0	15.0	27.0	06	070.1
47	09766	078	09.0	30.0	44.0	10	030.4
48	04204	075	22.0	45.0	15.0	08	020.6
49	07779	081	11.0	21.0	18.0	10	034.2
50	07057	066	10.0	18.0	30.0	07	071.9
51	11431	096	11.0	16.0	24.0	08	194.8
52	16447	078	12.0	14.0	22.0	07	169.1
53	07695	062	08.0	12.5	04.0	07	171.0
54	14512	072	20.0	20.0	11.0	11	094.0
55	04483	060	32.0	44.0	20.0	15	071.7
56	09507	084	22.0	22.0	32.0	16	035.7
57	08723	090	10.0	12.0	20.0	18	014.4
58	13186	090	10.0	16.0	17.0	15	107.9
59	16581	062	15.0	15.0	18.0	13	077.1
60	07471	075	11.0	17.0	15.0	11	074.7
61	03326	072	24.0	25.5	32.0	12	019.5
62	09073	078	12.0	14.0	17.0	07	075.0
63	05111	075	40.0	30.0	82.0	09	051.7
64	05441	081	18.0	10.0	10.0	07	108.5
65	05288	063	42.0	52.0	14.0	11	037.9
66	03934	084	04.0	04.0	06.0	11	049.7
67	03495	066	30.0	26.0	52.0	14	007.7
68	04730	075	13.0	15.0	16.0	08	268.8

TABLE D9 AUTONOMIC LABILITY SCORES

Subject No.	Conductance (RT)	Heart Rate (RT)	Conductance (T)	Heart Rate (T)
1	51.19	42.82	52.52	55.65
2	58.40	41.70	65.53	37.56
3	45.93	61.27	52.73	46.49
4	47.64	59.09	55.16	51.16
5	55.36	45.94	32.15	57.25
6	47.87	49.90	41.54	44.39
7	44.91	50.63	54.70	71.08
8	48.99	45.99	45.00	67.93
9	52.51	45.94	59.01	54.19
10	50.90	54.51	33.73	40.63
11	50.41	44.79	55.21	57.34
12	72.07	50.26	64.70	63.56
13	63.73	46.58	53.79	55.70
14	53.45	45.12	52.78	55.51
15	50.11	52.16	51.80	55.83
16	45.70	37.00	54.82	42.31
17	59.80	38.78	55.21	34.17
18	43.79	49.81	46.08	47.55
19	49.03	55.57	46.30	45.03
20	45.52	30.41	54.85	29.78
21	54.93	42.98	55.47	34.26
22	58.08	60.29	51.94	42.23
23	45.81	70.80	50.56	73.26
24	51.00	68.21	46.26	48.92
25	37.48	45.99	43.17	39.12
26	45.46	49.64	52.80	52.54
27	56.87	73.69	57.26	54.44
28	58.69	50.45	45.69	51.11
29	39.86	51.41	46.10	58.36
30	42.75	36.94	58.93	39.49
31	35.87	49.41	38.64	46.31
32	40.39	49.27	46.89	41.73
33	52.43	32.28	60.78	39.28
34	41.70	69.82	43.08	46.28
35	50.98	50.42	54.75	50.04
36	74.09	40.50	55.96	42.05
37	42.27	54.30	46.80	46.49
38	47.92	52.59	54.95	39.70
39	64.64	40.50	54.18	39.60
40	42.21	45.94	37.90	71.34
41	51.34	51.82	34.02	43.93
42	50.53	41.21	47.48	42.43
43	71.95	55.59	44.87	46.46
44	50.05	44.38	33.41	42.77
45	09.14	50.96	51.53	50.39
46	53.66	49.09	30.79	66.16

TABLE D9 cont.

Subject No.	Conductance (RT)	Heart Rate (RT)	Conductance (T)	Heart Rate (T)
47	47.39	45.79	42.86	55.35
48	43.15	42.00	49.73	68.61
49	40.50	43.28	35.27	49.65
50	52.61	81.40	46.80	70.28
51	57.53	46.04	58.83	42.32
52	65.42	74.53	67.24	42.05
53	48.66	58.49	47.21	39.69
54	73.88	36.17	79.83	46.19
55	40.87	42.62	44.00	49.33
56	46.56	40.03	52.59	62.09
57	47.44	62.29	53.33	57.34
58	44.15	45.00	71.52	55.83
59	61.61	49.30	87.30	42.41
60	47.92	56.62	55.84	46.24
61	37.55	39.82	44.25	65.84
62	43.24	59.86	50.45	47.19
63	46.61	60.66	48.24	51.68
64	48.78	44.88	57.11	56.30
65	49.05	47.74	53.69	47.87
66	37.20	53.21	41.16	58.16
67	56.39	51.66	48.35	35.52
68	53.12	41.91	46.82	51.37

TABLE D10

For each subject, line A shows Reversed RT
line B shows mean conductance change
line C shows mean basal conductance level

	Trial Nos.1-10	Trial Nos.11-20	Trial Nos. 21-30	Trial Nos.31-40	Trial Nos.41-50
Subject 4					
A	294.1	289.8	279.4	280.2	293.3
B	793.7	637.4	802.4	858.3	625.9
C	5918	5953	6135	6007	6578
Subject 5					
A	306.6	308.7	315.2	287.0	301.0
B	709.9	562.5	520.9	831.4	764.2
C	8775	9054	9742	11036	11771
Subject 8					
A	265.2	308.2	283.3	283.9	295.0
B	371.6	276.1	240.8	138.8	404.0
C	7983	7622	7829	7875	8253
Subject 17					
A	286.1	308.2	297.2	295.4	298.2
B	494.3	74.7	465.2	325.9	322.7
C	11050	11580	13792	15550	17246
Subject 28					
A	302.2	299.6	276.2	280.6	261.8
B	1136.0	751.0	570.2	417.1	69.1
C	9137	9549	10385	10875	12197
Subject 34					
A	299.4	267.8	301.1	280.3	284.3
B	123.8	87.1	97.6	116.9	101.5
C	3911	3973	4231	4405	4502
Subject 39					
A	259.6	241.7	221.0	226.2	190.0
B	1200.0	370.5	432.8	154.2	51.2
C	15721	16530	16009	16133	15629
Subject 42					
A	256.6	266.7	277.1	241.9	258.7
B	1130.0	687.2	694.8	389.2	370.1
C	4990	5350	5817	6220	6476

TABLE D10 cont.

	Trial Nos.1-10	Trial Nos.11-20	Trial Nos.21-30	Trial Nos.31-40	Trial Nos.41-50
Subject 43					
A	278.6	274.7	280.1	276.6	256.4
B	1019	1260	1188	1178	831.6
C	14087	15772	16902	17649	18130
Subject 68					
A	268.7	285.8	291.4	292.8	269.0
B	419.2	106.1	26.9	50.5	-
C	7987	7670	8098	8254	8404
Subject 14					
A	174.6	224.7	209.7	192.7	178.3
B	735.3	513.5	197.0	32.0	-
C	5272	6794	7969	8323	7331
Subject 15					
A	149.1	233.1	226.7	186.6	217.2
B	769.9	235.4	579.4	504.3	554.6
C	8773	9065	9434	9571	9805
Subject 18					
A	188.1	158.6	180.7	220.6	183.2
B	572.3	476.5	533.2	558.6	687.4
C	4785	4838	4856	5201	5519
Subject 25					
A	208.3	218.6	211.3	228.1	245.3
B	294.8	124.5	123.1	21.5	50.2
C	3354	3407	3450	3667	3824
Subject 35					
A	225.1	228.3	227.2	207.0	198.0
B	445.0	67.3	50.2	25.2	9.1
C	5175	5466	5698	5937	5785
Subject 37					
A	218.9	237.5	211.3	233.1	237.9
B	208.2	142.2	163.2	176.8	142.2
C	3528	3279	3388	3565	3497
Subject 49					
A	235.4	243.7	224.3	221.5	219.2
B	617.1	206.3	137.7	-	512.6
C	9851	8875	10772	12199	13462

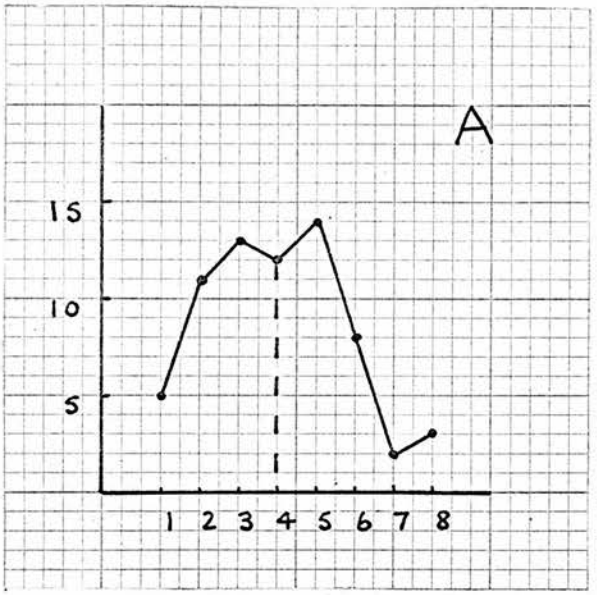
TABLE D10 cont.

	Trial Nos.1-10	Trial Nos.11-20	Trial Nos.21-30	Trial Nos.31-40	Trial Nos. 41-50
Subject 53					
A	215.3	242.8	224.0	220.3	248.1
B	236.8	157.7	111.0	40.5	15.2
C	4655	5313	6229	6927	7858
Subject 56					
A	196.4	213.9	217.7	224.7	240.4
B	898.4	397.2	643.2	688.0	124.8
C	6717	5651	5804	6043	6335
Subject 61					
A	169.1	227.7	192.2	211.2	188.0
B	154.0	101.0	53.3	66.2	64.1
C	3381	3147	3125	3170	3401

APPENDIX 2

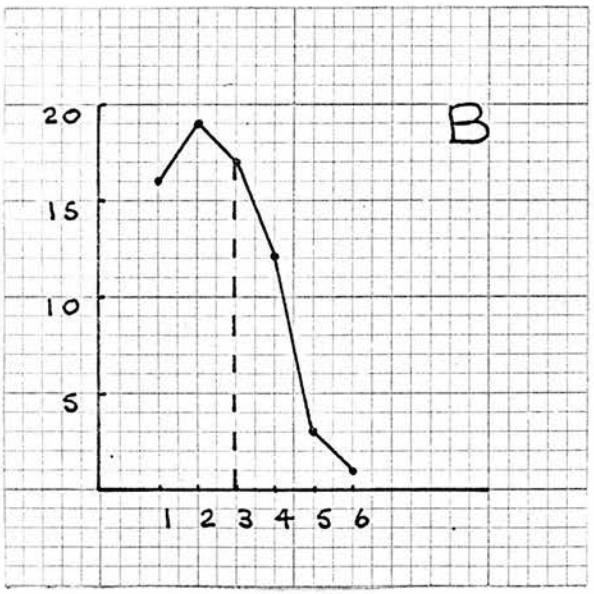
FREQUENCY DISTRIBUTIONS

A. Mean of the best ten reaction times



		n
1	180 - 189.9	5
2	190 - 199.9	11
3	200 - 209.9	13
4	210 - 219.9	12
5	220 - 229.9	14
6	230 - 239.9	8
7	240 - 249.9	2
8	250 - 259.9	3

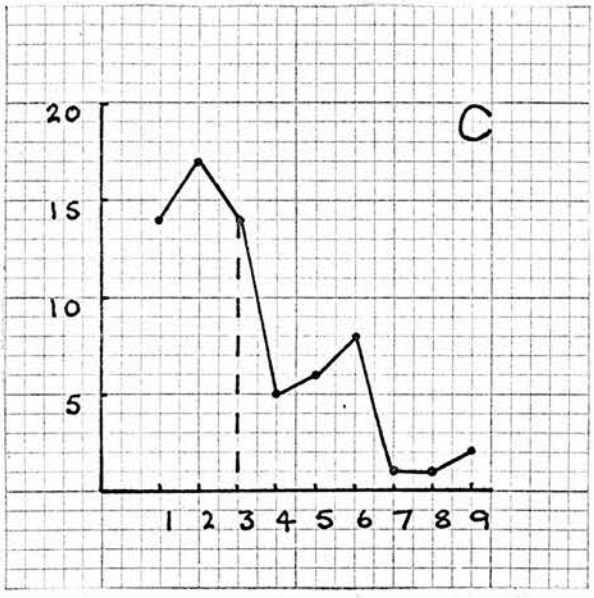
B. Standard Deviation of reaction time



		n
1	20 - 29.9	16
2	30 - 39.9	19
3	40 - 49.9	17
4	50 - 59.9	12
5	60 - 69.9	3
6	70 - 79.9	1

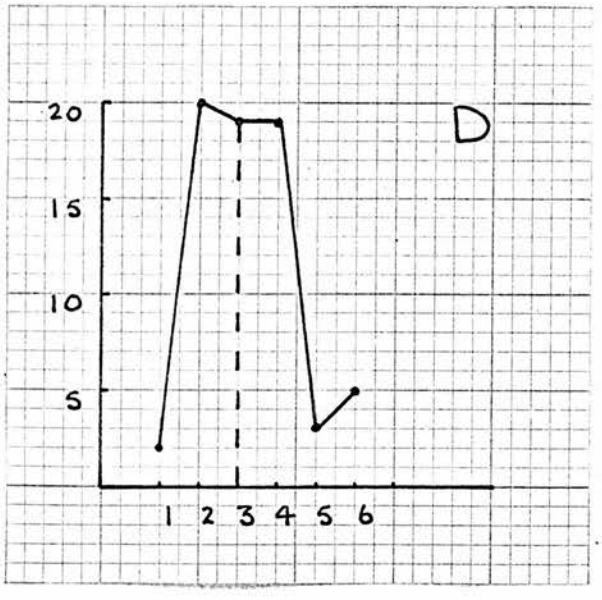
FREQUENCY DISTRIBUTIONS

C. Pursuit rotor tracking. Time on target.



				n
1	0	-	29.9	14
2	30	-	59.9	17
3	60	-	89.9	14
4	90	-	119.9	5
5	120	-	149.9	6
6	150	-	179.9	8
7	180	-	209.9	1
8	210	-	239.9	1
9	240	-	269.9	2

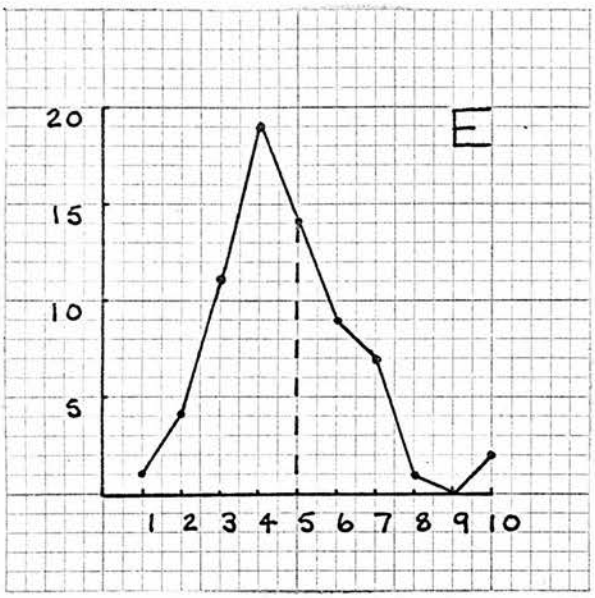
D. Word recall score.



				n
1	0	-	4.5	2
2	5	-	9.5	20
3	10	-	14.5	19
4	15	-	19.5	19
5	20	-	24.5	3
6	25	-	29.5	5

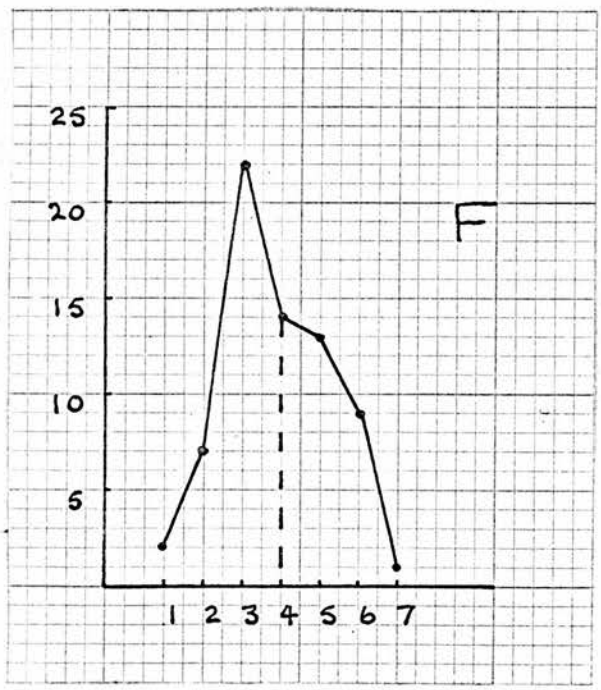
FREQUENCY DISTRIBUTIONS

E. Threshold scores



		n
1	1.5 - 1.9	1
2	2.0 - 2.4	4
3	2.5 - 2.9	11
4	3.0 - 3.4	19
5	3.5 - 3.9	14
6	4.0 - 4.4	9
7	4.5 - 4.9	7
8	5.0 - 5.4	1
9	5.5 - 5.9	0
10	6.0 - 6.4	2

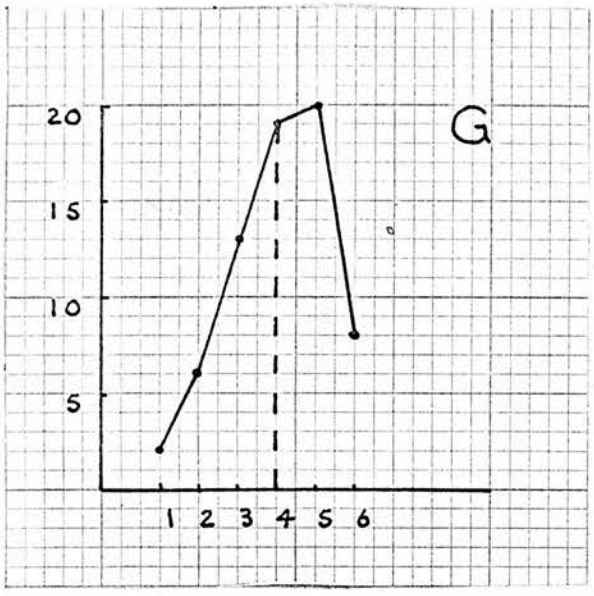
F. N Scale scores



		n
1	0 - 2	2
2	3 - 5	7
3	6 - 8	22
4	9 - 11	14
5	12 - 14	13
6	15 - 17	9
7	18 - 20	1

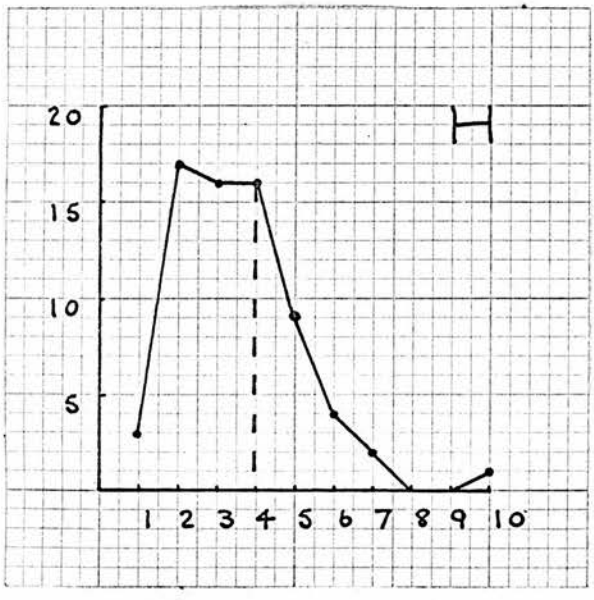
FREQUENCY DISTRIBUTIONS

G. E Scale scores



		n
1	3 - 5	2
2	6 - 8	6
3	9 - 11	13
4	12 - 14	19
5	15 - 17	20
6	18 - 20	8

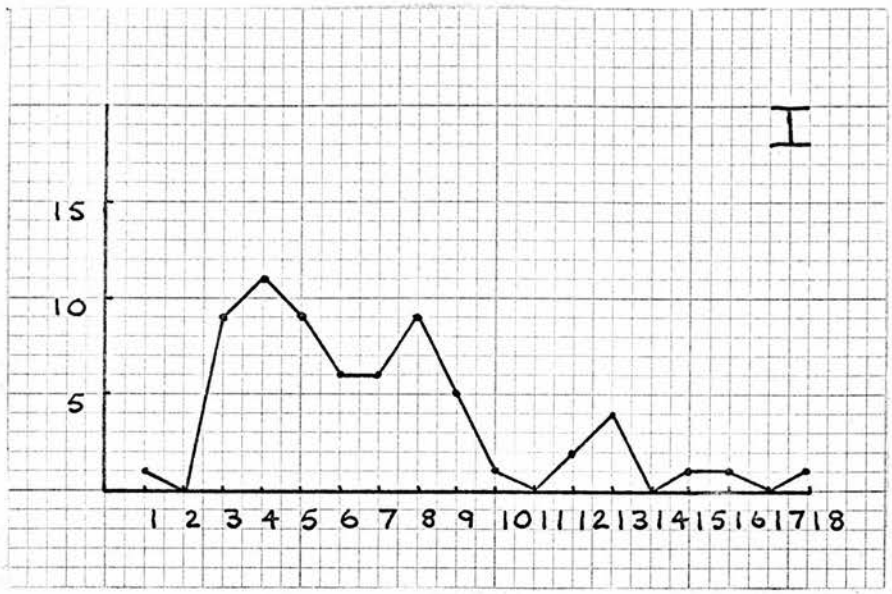
H. Overall mean figure reversal rate



		n
1	0 - 4.9	3
2	5 - 9.9	17
3	10 - 14.9	16
4	15 - 19.9	16
5	20 - 24.9	9
6	25 - 29.9	4
7	30 - 34.9	2
8	35 - 39.9	0
9	40 - 44.9	0
10	45 - 49.9	1

FREQUENCY DISTRIBUTIONS (I - R inclusive all recorded during the first five minutes of the session)

I. Mean basal conductance level (Session Two)

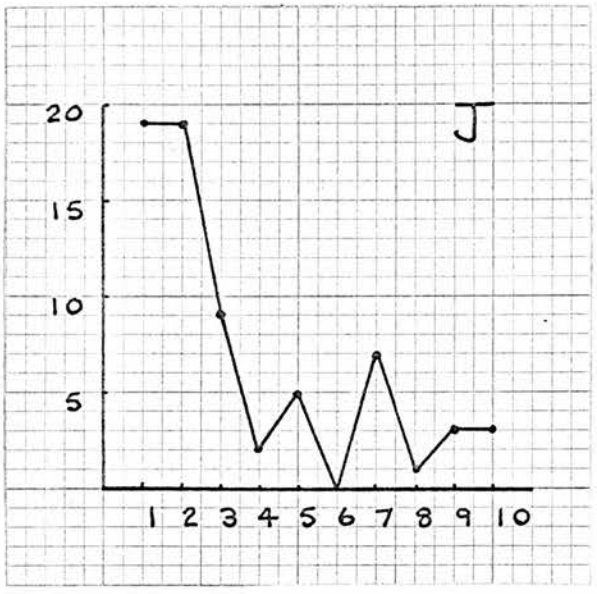


				n
1	0000	-	999	1
2	1000	-	1999	0
3	2000	-	2999	9
4	3000	-	3999	11
5	4000	-	4999	9
6	5000	-	5999	6
7	6000	-	6999	6
8	7000	-	7999	9
9	8000	-	8999	5
10	9000	-	9999	1
11	10000	-	10999	0
12	11000	-	11999	2
13	12000	-	12999	4
14	13000	-	13999	0
15	14000	-	14999	1
16	15000	-	15999	1
17	16000	-	16999	0
18	17000	-	17999	1

Two cases, 33,373 and 23,059, lie outside this range.

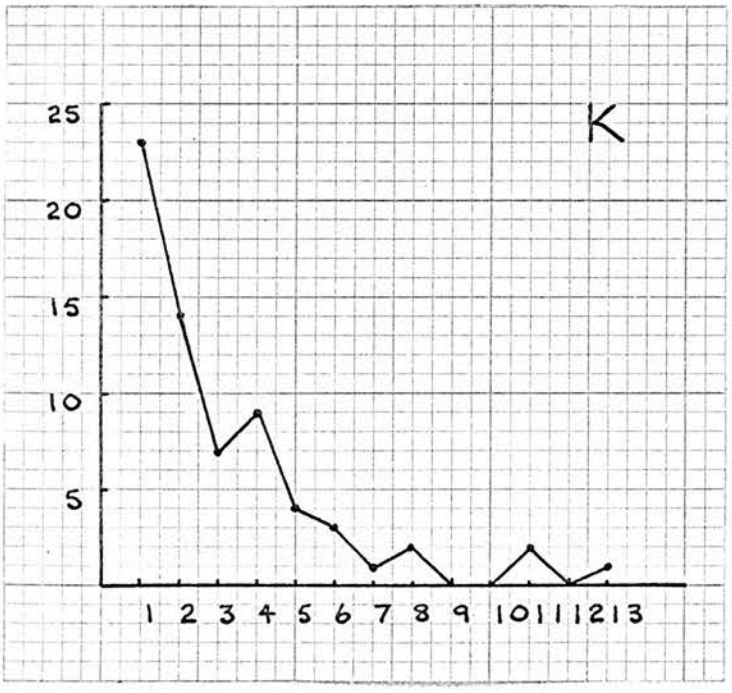
FREQUENCY DISTRIBUTIONS

J. Number of galvanic skin responses (Session Two)



				n
1	0	-	3	19
2	4	-	7	19
3	8	-	11	9
4	12	-	15	2
5	16	-	19	5
6	20	-	23	0
7	24	-	27	7
8	28	-	31	1
9	32	-	35	3
10	36	-	39	3

K. Mean conductance change (Session Two)

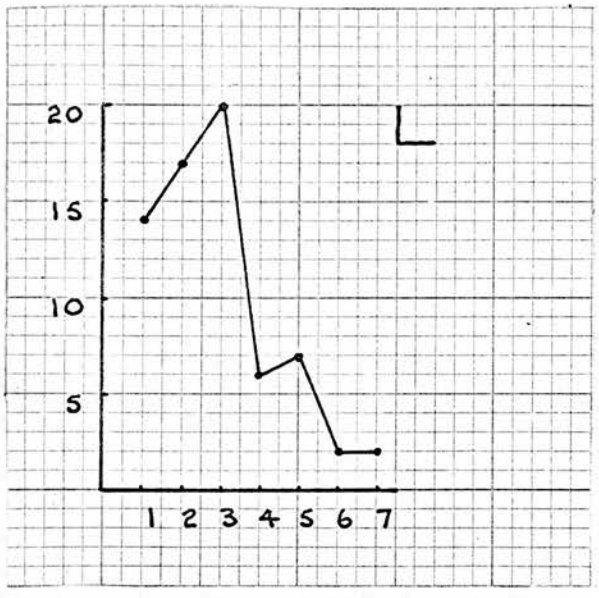


				n
1	0	-	99	23
2	100	-	199	14
3	200	-	299	7
4	300	-	399	9
5	400	-	499	4
6	500	-	599	3
7	600	-	699	1
8	700	-	799	2
9	800	-	899	0
10	900	-	999	0
11	1000	-	1099	2
12	1100	-	1199	0
13	1200	-	1299	1

Two cases, 1711 and 2220, lie outside this range.

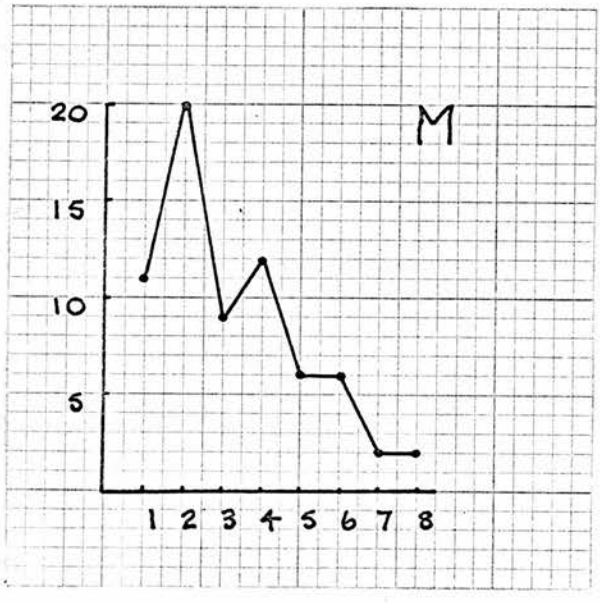
FREQUENCY DISTRIBUTIONS

L. Mean integrated electromyogram (forehead) (Session Two)



				n
1	0	-	4.5	14
2	5	-	9.5	17
3	10	-	14.5	20
4	15	-	19.5	6
5	20	-	24.5	7
6	25	-	29.5	2
7	30	-	34.5	2

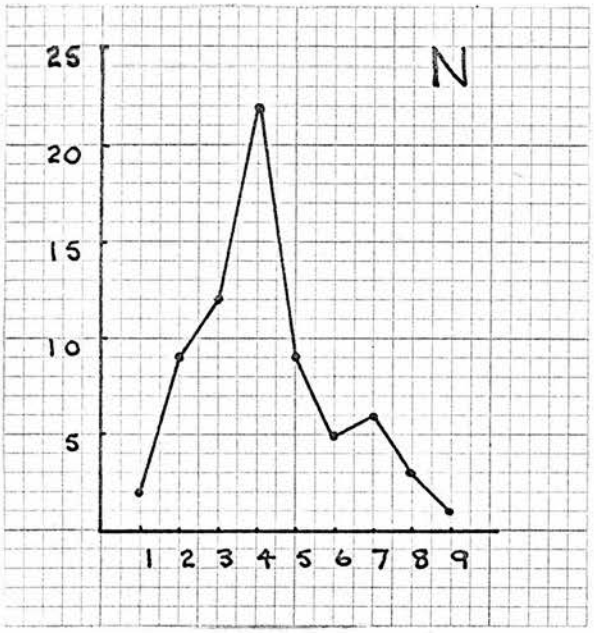
M. Mean integrated electromyogram (neck) (Session Two)



				n
1	5	-	9.5	11
2	10	-	14.5	20
3	15	-	19.5	9
4	20	-	24.5	12
5	25	-	29.5	6
6	30	-	34.5	6
7	35	-	39.5	2
8	40	-	44.5	2

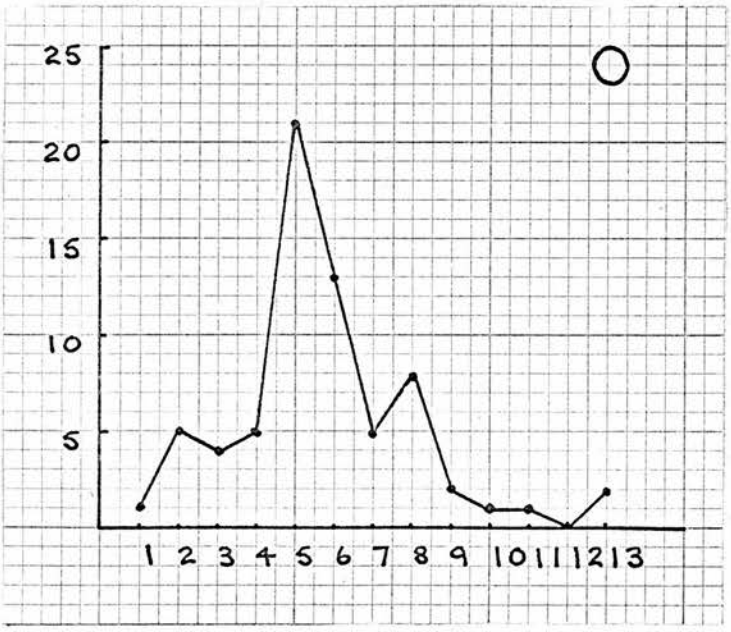
FREQUENCY DISTRIBUTIONS

N. Mean integrated electromyogram (upper arm) (Session Two)



				n
1	0	-	4.5	1
2	5	-	9.5	9
3	10	-	14.5	12
4	15	-	19.5	22
5	20	-	24.5	9
6	25	-	29.5	5
7	30	-	34.5	6
8	35	-	39.5	3
9	40	-	44.5	1

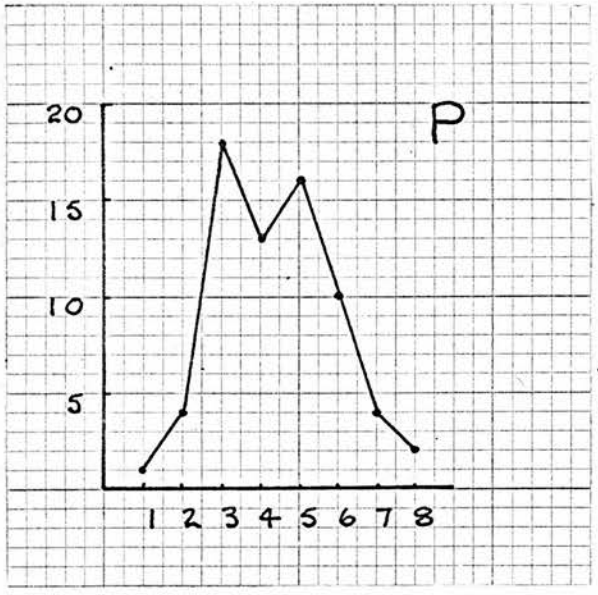
O. Mean heart rate (Session Two)



				n
1	50	-	54.9	1
2	55	-	59.9	5
3	60	-	64.9	4
4	65	-	69.9	5
5	70	-	74.9	21
6	75	-	79.9	13
7	80	-	84.9	5
8	85	-	89.9	8
9	90	-	94.9	2
10	95	-	99.9	1
11	100	-	104.9	1
12	105	-	109.9	0
13	110	-	114.9	2

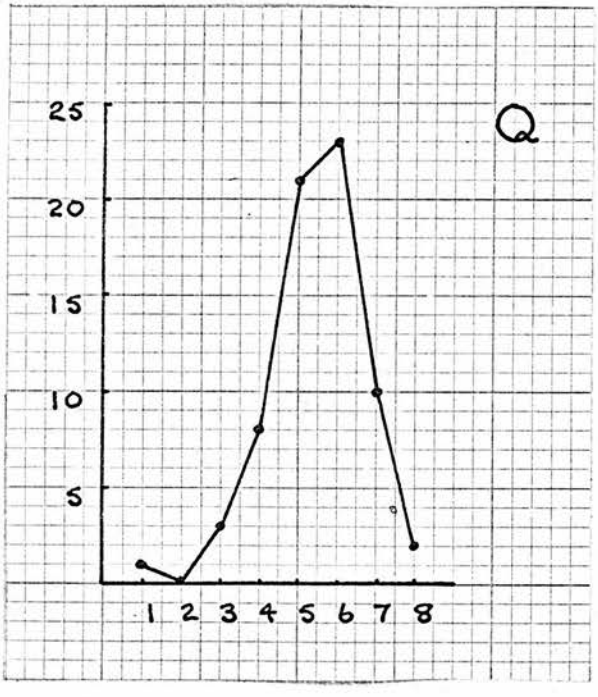
FREQUENCY DISTRIBUTIONS

P. Mean respiration rate (Session Two)



				n
1	8	-	9.9	1
2	10	-	11.9	4
3	12	-	13.9	18
4	14	-	15.9	13
5	16	-	17.9	16
6	18	-	19.9	10
7	20	-	21.9	4
8	22	-	23.9	2

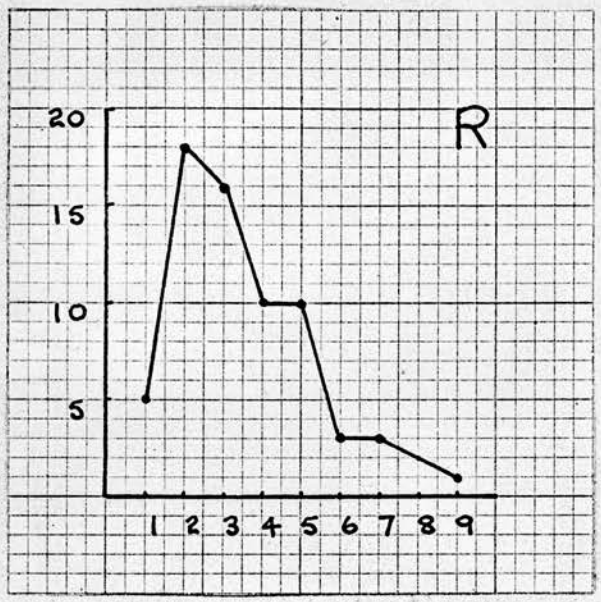
Q. Mean inspiration/respiration ratio (Session Two)



				n
1	18	-	21	1
2	22	-	25	0
3	26	-	29	3
4	30	-	33	8
5	34	-	37	21
6	38	-	41	23
7	42	-	45	10
8	46	-	49	2

FREQUENCY DISTRIBUTIONS

R. Mean eyeblink rate (Session One)



				n
1	0	-	4.9	5
2	5	-	9.9	18
3	10	-	14.9	16
4	15	-	19.9	10
5	20	-	24.9	10
6	25	-	29.9	3
7	30	-	34.9	3
8	35	-	39.9	2
9	40	-	44.9	1

APPENDIX 3 ORDER OF PRESENTATION OF PAIRED ADJECTIVES

1.	Waggish	Jocose
2.	Classic	Ruddy
3.	Obese	Bulbous
4.	Tardy	Absurd
5.	Acute	Astute
6.	Spongy	Transverse
7.	Yearly	Inverse
8.	Clannish	Fishy
9.	Crucial	Glassy
10.	Concave	Unseen
11.	Fiscal	Random
12.	Oblong	Lengthy
13.	Fallow	Carnal
14.	Yeasty	Spumy
15.	Festive	Slender
16.	Fiendish	Mellow
17.	Zigzag	Forked
18.	Early	Pristine
19.	Feline	Hilly
20.	Fleshy	Standard
21.	Lawless	Distinct
22.	Urbane	Ample
23.	Abstract	Abstruse
24.	Verdant	Captious
25.	Western	Rounded
26.	Dulcet	Tuneful
27.	Natal	Nascent
28.	Limpid	Lucid
29.	Noxious	Toxic
30.	Erect	Fancy

APPENDIX 3 cont. ORDER OF PRESENTATION OF SINGLE 'STIMULUS' ADJECTIVES

1. Tardy
2. Fiendish
3. Lawless
4. Clannish
5. Fiscal
6. Zigzag
7. Dulcet
8. Verdant
9. Yearly
10. Festive
11. Fleshy
12. Fallow
13. Urbane
14. Erect
15. Early
16. Western
17. Acute
18. Classic
19. Natal
20. Abstract
21. Noxious
22. Crucial
23. Concave
24. Feline
25. Limpid
26. Waggish
27. Obese
28. Oblong
29. Yeasty
30. Spongy

APPENDIX 4 The P.E.N. Inventory

P=

Name_____age_____sex_____ E=

N=

L=

I N S T R U C T I O N S

Please answer each question by putting a circle around the 'YES' or the 'NO' following the question. There are no right or wrong answers, and no trick questions. Work quickly and do notthink too long about the exact meaning of the question.

REMEMBER TO ANSWER EACH QUESTION

1. Are you more distant and reserved than most people?____YES NO
2. Do you find it hard to get going some mornings?_____YES NO
3. Do most things taste the same to you?_____YES NO
4. If you say say you will do something do you always keep your promise, no matter how inconvenient it might be to do so?_____YES NO
5. Can you get a party going?_____YES NO
6. Can you usually make up your mind easily?_____YES NO
7. Do you enjoy hurting people you love?_____YES NO
8. Once in a while do you lose your temper and get angry?_YES NO
9. Would you do almost anything for a dare?_____YES NO
10. Have you ever been afraid of losing your mind?_____YES NO
11. Are you generally in good health?_____YES NO
12. Do you occasionally have thoughts and ideas that you would not like other people to know about?_____YES NO
13. Would you enjoy hunting, fishing and shooting?_____YES NO
14. Do you do much day-dreaming?_____YES NO
15. Was your mother a good woman?_____YES NO
16. Are <u>all</u> your habits good and desirable ones?_____YES NO

17. Do you nearly always have a "ready answer" when people talk to you? YES NO

18. Do you find it hard to keep your mind on what you are doing? YES NO

19. Have you had more trouble than most? YES NO

20. Do you sometimes gossip? YES NO

21. Are you rather lively? YES NO

22. Are you ever "off your food"? YES NO

23. Do you worry a lot about catching diseases? YES NO

24. Would you always declare <u>everything</u> at the customs, even if you knew that you could never be found out? YES NO

25. Do you like plenty of bustle and excitement around you? YES NO

26. Do you often feel fed up? YES NO

27. Do you like mixing with people? YES NO

28. Have you had an awful lot of bad luck? YES NO

29. Have you ever been late for an appointment or work? YES NO

30. Do you get depressed in the mornings? YES NO

31. Are there several people who keep trying to avoid you? YES NO

32. Of all the people you know, are there some whom you definitely do not like? YES NO

33. Would you call yourself happy-go-lucky? YES NO

34. Does your mood often go up and down? YES NO

35. Do you let your dreams warn or guide you? YES NO

36. Do you sometimes talk about things you know nothing about? YES NO

37. Can you usually let yourself go and enjoy yourself a lot at a gay party? YES NO

38. Do you sometimes feel you don't care what happens to you? YES NO

39. Is there someone who is responsible for most your troubles? YES NO

40. As a child, did you always do as you were told immediately and without grumbling? YES NO

41. Do you like people around you? YES NO

42. Do you ever feel "just miserable" for no good reason? YES NO

43. Do people generally seem to take offence easily? YES NO

44. Do you sometimes get cross? YES NO

45. Do you like going out a lot? YES NO

46. Are you often troubled about feelings of guilt? YES NO

47. Would you take drugs which may have strange or dangerous effects? YES NO

48. Do you sometimes laugh at a dirty joke? YES NO

49. Do you like practical jokes? YES NO

50. Do you feel self pity now and again? YES NO

51. Did you love your mother? YES NO

52. Are you completely free from prejudices of any kind? YES NO

53. Do you normally prefer to be alone? YES NO

54. Do you worry a lot about your looks? YES NO

55. Do you have enemies who wish to harm you? YES NO

56. Do you sometimes boast a little? YES NO

57. Do you find it hard to show your feelings? YES NO

58. Do you often feel very weak all over? YES NO

59. Do your friendships break up easily without it being your fault? YES NO

60. Do you always answer a personal letter as soon as you can after you have read it? YES NO

61. Would you call yourself talkative?_____YES NO

62. Do you sometimes feel uneasy indoors?_____YES NO

63. Do people mean to say and do things to annoy you?_____YES NO

64. Do you sometimes put off until tomorrow what you ought to do today?_____YES NO

65. When you were a child did you often like a rough and tumble game?_____YES NO

66. Have you always thought of yourself as different to others?_____YES NO

67. Was your father a good man?_____YES NO

68. Have you sometimes told lies in your life?_____YES NO

69. Do you like telling jokes or funny stories to your friends?_____YES NO

70. Have you ever wished you were dead?_____YES NO

71. Would you have been more successful if people had not put difficulties in your way?_____YES NO

72. Would you rather win than lose a game?_____YES NO

73. Do you make friends easily with members of your own sex?_____YES NO

74. Do you usually work by fits and starts?_____YES NO

75. Would it upset you a lot to see a child or animal suffer?_____YES NO

76. When you make new friends do you usually make the first move?_____YES NO

77. When you are in a crowded place like a bus do you worry about dangers of infection?_____YES NO

78. Do things sometimes seem as if they were not real?____YES NO

APPENDIX 5

Figure 1

1 sec.

Eyeblink record showing eyeblink 'blips'.

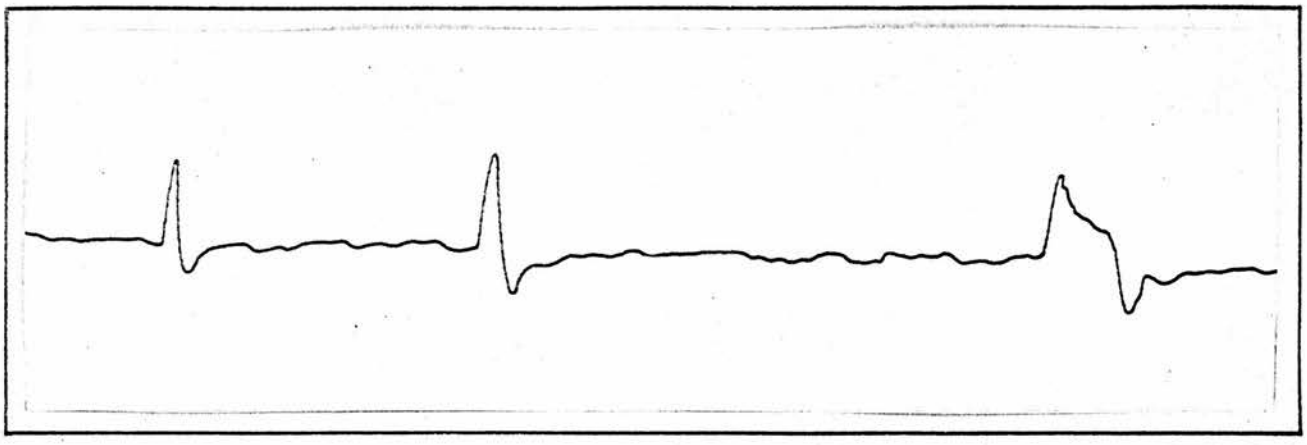


Figure 2

Eyeblink record showing the effect of large eye and head movements.

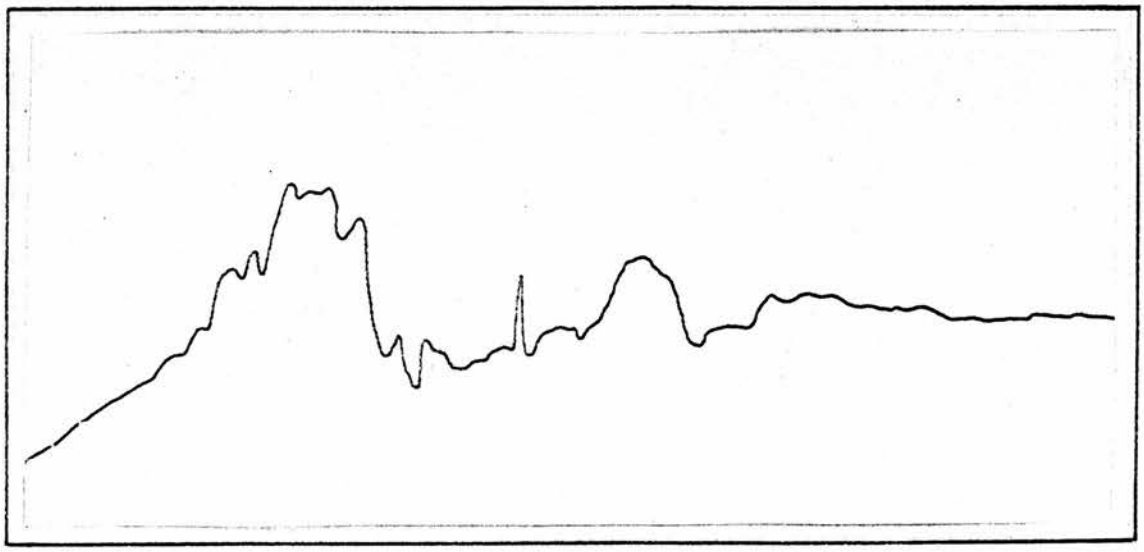
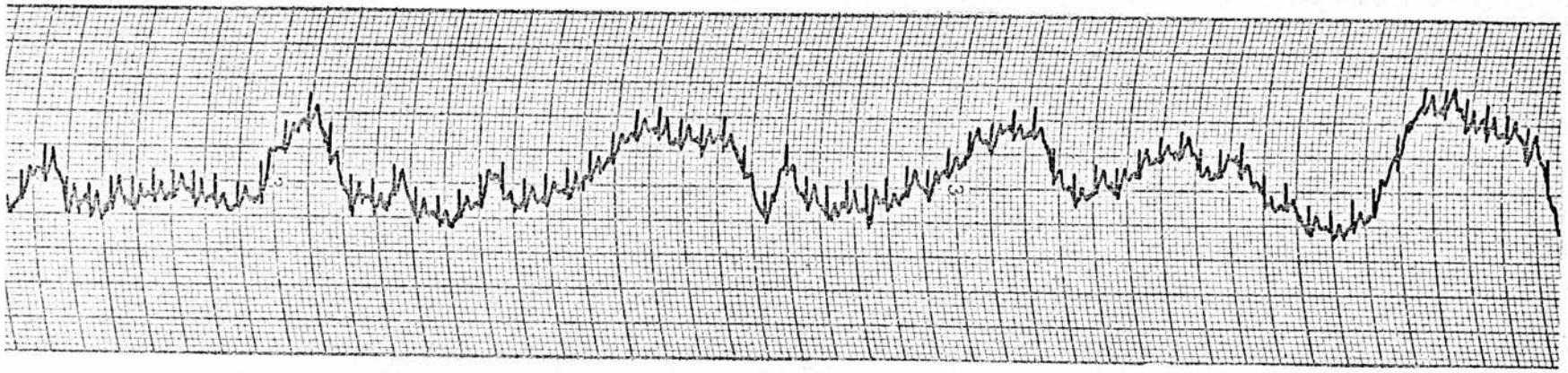


Figure 3

Electrocardiogram during performance showing fluctuating baseline.



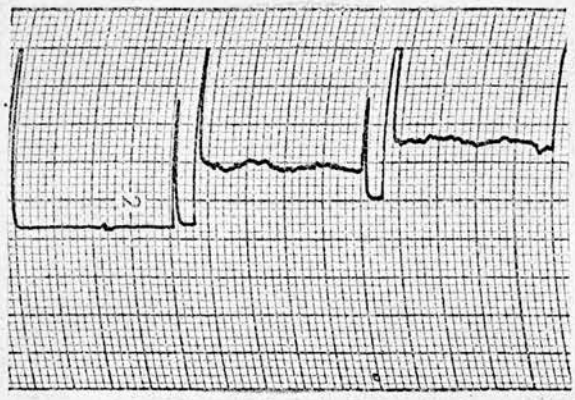


Figure 4

A section of EMG record

Figure 5

Resting respiration record

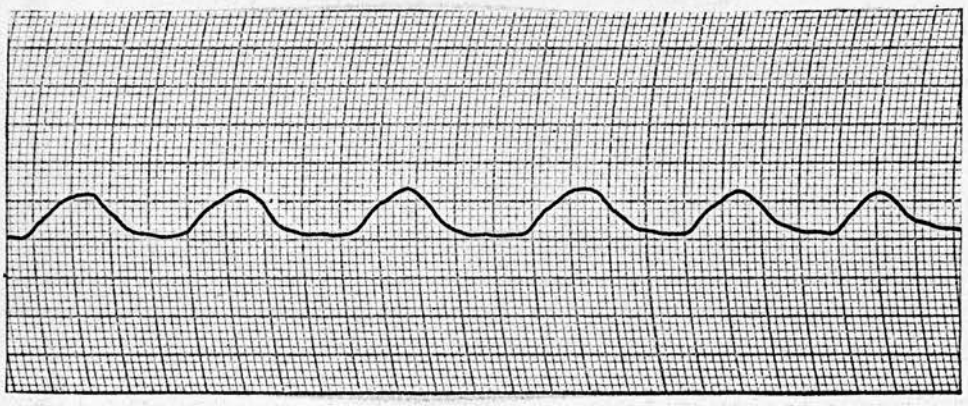


Figure 6

Respiration during reaction time task showing sudden intake of breath on responding.

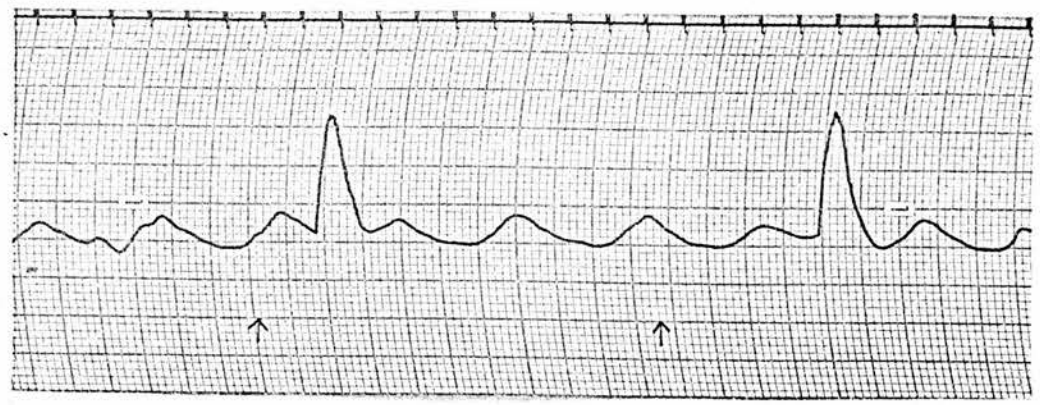


Figure 7

Respiration during reaction time task showing holding of breath on presentation of warning light (arrows).